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An interfirm competition model for deriving empirical estimates of supply response

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AN INTERFIRM COMPETITION MODEL FOR DERIVING EMPIRICAL ESTIMATES OF SUPPLY RESPONSE

by

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I. SUPPLY RESPONSE AND PUBLIC POLICY IN AGRICULTURE

Public policy has a long history of influence on the development of agriculture in the United States. The Homestead Act and similar policies allowed and promoted the distribution of land at low prices through Government machinery. The creation of the U.S. Department of Agriculture and the Land Grant Act to establish agricultural colleges were public policies to promote research in agriculture and disseminate the research findings among farmers. The Smith-Lever Act of 1914 which created the agriculture extension services and the Smith-Hughes Act of 1917 which provided federal funds to public schools to create vocational agriculture departments are other important public policies that influenced the development of agriculture.

The success of these types of public policies was an important contributing factor to the progression of the agriculture sector in the United States to a mature industry with new problems. The distribution of land, knowledge, and other factors of production at public expense created an agriculture production plant that was capable of producing more food than could be sold in the market place.

The public policies for agriculture were then expanded to include compensation policies as well as developmental policies. The compensation policies were introduced to try to improve the level and stability of farm income through expansion of marketings and reduction in output. Heady notes the introduction of compensation policies by stating that (16, p. 11):

> The problem of farm surplus capacity first showed up in the 1920's when output started growing more rapidly than demand, became acute in the 1930's, and returned immediately in the 1950's after the cessation of war-generated demand. The public, through governmental programs, took direct part in trying to solve the surplus and related income problems of agriculture as early as 1933. We have been so engaged ever since.

A. Production Economics and Policy Analysis

Production economics as a separate discipline within economics was established during the 1920's. In discussing the evolvement of production economics, Butcher writes as follows (6, p. 1475):

> The developments of the 1920's ... saw an integration of these heretofore separate streams of thought. The practical problem-solving orientation was retained, but economic theory - especially the theory of the firm - and deductive thought in general came to be regarded as both a model for testing the logical validity of inductively derived conclusions and a powerful tool for attacking problems too complex for traditional approaches. This period saw the emergence of synthetic or simulated economic models in the form of farm and enterprise budgets. Statistical analysis also came into use as a tool for analysis and estimation of economic and physical relations.

Agricultural production economics has been defined by Heady as "... an applied field of science wherein the principles of choice are applied to the use of capital, labor, land, and management resources in the farming industry" (15, p. 8).

The emergence of production economics and the application of this field to agriculture then was in sequence with the beginning of the surplus production capacity problem on farms and the formulation of compensation policies. Butcher (6, p. 1476) pointed out the early involvement of production economists in the emerging policy question on surplus production capacity when he stated that:

> Production economists worked on planning of depression-era recovery programs and then continued to participate in World War II "Capacity Studies" and postwar adjustment programs. One very logical route to these aggregate studies was through realization that results from studies of individual enterprises and firms have aggregate and policy implications. They could be used both to determine the policy actions needed to achieve certain goals for firms and individuals and also to predict the likely effects of proposed or contemplated policy alternatives. Soon, studies of firms were being made explicitly for the purpose of providing guides to policy-making.

B. Supply and Demand: The Parameters of Market Equilibrium

The more formal theory of production and the firm, based on marginal analysis, was the primary forerunner of the emergence of production economics. The theory of production now had an aura of completeness that could be carried forward into the theory of markets for products and backward into the theory of markets for factors of production. It also provided the means to determine optimal patterns of production organization, the problem of allocation of resources. Finally, there was a new ability to formalize the cost of the production by a firm and the supply conditions of the industry.

When the cost and supply side of business operation is brought together with the revenue side of business operation - the theory of demand - the market price and output for a firm and for the industry are determined. Production economists thus have had these two parameters, supply and demand, to work with as they have investigated the possible solutions to the surplus production capacity problem of the agriculture sector.

As intelligence was developed on the problem of surplus production capacity in agriculture, the majority of production economists came to believe that the solution to the problem rested in the adjustment of the supply of agriculture products. Studies of the aggregate demand for farm products revealed the inelastic nature of this function. Lower prices would not allow farmers to sell significantly increased quantities of their products. Population growth, an increase in the number of consumers, was the primary factor that would allow more farm products to be sold. Thus the demand for agricultural products is quite stable and difficult to manipulate.

At a conference on adjustment problems in agriculture sponsored by the North Central Farm Management Research

Committee, Collins and Mehren stated that (8, p. 73):

> Efforts to manipulate food demand through advertising and other promotional methods cannot be expected to serve as a fully effective method of solving the farm problem and achieving future economic adjustments. If this is true, then the mechanism associated with achieving adjustment of farm production should be analyzed.

In agreeing with Collins and Mehren, Cochrane stated (7, p. 99):

> Farmers and their leaders, ..., have to find a way to adjust production to demand, commodity by commodity, to yield reasonably good, and stable farm incomes.

Halcrow, in summarizing the conference on agriculture adjustment problems, also reached the same conclusion and stated (13, p. 309):

> Expanding the demand for farm products, however, is not the solution to the farm problem in the next decade. Our production potential is too large. Demand is, of course, important. But changes in demand alone will not be sufficient to bring returns to labor resources in agriculture that are equal to those outside of agriculture.

Other prominent production economists such as Heady and Schultz have also pointed out the need for supply adjustment if the agriculture sector is to have returns to resources that are comparative with other sectors of the economy. Heady writes as follows: (16, p. 6):

> Directly, the farm problem does appear as one of too much production. Since the war, farm population has more than halved, and the work force in agriculture has declined by 40 percent. Yet the capacity of agriculture to produce food has grown constantly. We can produce 10 percent more food annually than required to meet domestic and commercial export needs

> at prices acceptable to the farm sector. And we can do so with one-eighth less land than needed a half-century ago.

In a very direct statement, Schultz asserts that (30, p. 748):

> Tell me what the supply of farm products will be five or ten years from now, and I shall give you meaningful answers to the more important economic problems of agriculture. This is not an idle promise. Most of the relevant knowledge of consumption and demand is at hand and the important economic problems of agriculture call primarily for adjustments in production.

C. Focus on Supply Adjustment

During the late 1950's and the 1960's, production economists have invested a very significant quantity of professional man-years and other resources in studying the problem of supply adjustment in agriculture. This was, of course, the appropriate action to pursue to try to help solve the surplus capacity problem and the accompanying problems of low returns to resources and adjustments in resource use. Again, Miller pointed out the appropriateness and usefulness of this work to all who are concerned with agriculture when he stated that (26, p. 1):

> Knowledge of supply relationships provides a basis for understanding agricultural adjustments to changing demands, changing input supplies and new technologies. An understanding of both supply relationships and the agricultural adjustment process is invaluable to decision makers at all levels of the agricultural economy. It enables farmers to plan their operations for higher profits. It allows farm input suppliers to accurately predict the demand for their products. It provides policy makers and consumers with better insights into the changing role of agriculture.

This period of emphasis on gathering intelligence on supply relationships produced numerous important research findings and publications. Three of the major studies will be discussed briefly to emphasize the degree of attention that production economists have given to this general area of supply response and resource adjustment in the past few years.

1. <u>Interregional competition or spatial equilibrium models</u>

One important type of interregional competition model that focused on the production-resource problem in agriculture is commonly referred to as the Heady-Egbert model. This linear programming model delineated the United States into one hundred and four production regions and ten consuming regions. The products considered were food wheat, feed wheat, and a feed grain composite consisting of corn, oats, barley and grain sorghums. The demand for these products in each consuming region was taken as given and the objective function of the model was to minimize the cost of producing the amount of products needed to meet the demand.

As additional research resources and larger electronic computers became available, significant additions to the Heady-Egbert model have been made by Whittlesey, Skold, Brokken, Mayer and Eyvindson (46, 35, 5, 25, 11). These students of Heady added more producing and consuming regions to the model and considered competing and complementary products such as soybeans, cotton, and livestock. The cost of transportation between regions was added to the Heady-Egbert model as were classes of land and production cost differentiation by farm size. These models have been used to provide intelligence on supply and resource adjustment problems under varying demand conditions and public compensation policies.

As an example of the scope of these additions to the Heady-Egbert model, the original model by Egbert required a matrix of a 124 x 3,120 order while the most recent work by Eyvindson has grown to a 6,838 x 41,677 matrix. To construct and solve a linear programming model of this size is truly a phenomenol accomplishment.

Another major addition to the Heady-Egbert model is by Hall (14). Hall's model was a quadratic programming model in which demand functions were included to make the model a true equilibrium model of the agriculture sector.

2. Regional adjustment studies

The regional adjustment studies of the 1960's undoubtedly had more investment of research support and professional man years than any other single approach to providing information on supply response. Of the six regional adjustment studies, the Lake States dairy study was the first one to be initiated in 1958. Similar studies were also undertaken in the Northeast, South, Corn Belt, Great

Plains and the West.

These studies were cooperative ventures by the State Agricultural Experiment Stations and the Farm Production Economics Division of the Economic Research Service, U.S. Department of Agriculture. Sharples lists the primary objectives of the regional adjustment studies as (32, p. 354):

> (1) to estimate adjustments needed in resource allocation on farms to maximize profits, (2) to estimate regional supply response, and (3) to determine an equilibrium supply-demand condition for a region and then for individual farms.

The research methods used in these studies revolved around representative farms. A linear programming model of each representative farm was variable priced to generate a synthetic supply curve for the products of major importance in the region. The five major components of the research approach, following Barker and Stanton were (1, p. 701):

> (1) stratify all farms within a region into homogeneous groups, (2) define a representative farm for each stratum, (3) derive supply functions for each farm, (4) aggregate the supply functions, and (5) remove the model's simplifying assumptions and adjust the results accordingly in order to make predictions or prescriptions.

As an example of the research support and professional man years invested in these studies we can look at the Corn Belt study (NC-54). A total of fifty-four professional personnel participated in contributing projects and over thirty-five publications including eighteen theses came out of these projects.

The contribution of professional time and resulting publication lists from the other five regional adjustment studies are comparable to the Corn Belt study.

3. A national model of agricultural production response

In 1963 the Farm Production Economics Division of the Economic Research Service, U.S. Department of Agriculture set up a task force to determine what should be done to strengthen the Division's ability to answer the policy questions asked by the Administration and Congress. As Sharples and Schaller have stated (33, p. 1523):

> The specific need was for a systematic framework that would provide timely, short-run estimates of production, resource use, income, and related variables under alternative government farm programs.

The national model project was initiated in 1964 with the objective of providing the needed timely intelligence through a systematic and quantitative framework.

The methodology they chose to work with was to construct aggregate linear programming models, one for each of about ninety resource situations. Each of the linear programming models were thus to represent the aggregate of resources on a group of farms that were assumed to display similar patterns of production response. These models were solved independently to obtain estimates of production response for the crop year immediately ahead. To obtain these short-run estimates behavioral restraints that would limit the amount of change in the production of commodities from one year to the next were included in the models.

As this work evolved a team of ten to twelve professionals have participated in the project. Tne original national model has been integrated into a broader research approach called the "Aggregate Production Analysis System" and work is continuing to make the system even more useful to answer policy questions.

II. SUPPLY RESPONSE AND TECHNIQUES OF ESTIMATION

The vast amount of research work undertaken to fulfill the recognized need of more intelligence on supply response in agriculture has filled many volumes. The journals and other literature of agriculture economics report many studies on supply response in which formal research methods were used and others in which informal methods were used. Some studies concentrated on the micro or firm level while others concentrated on the macro or industry level. In some studies, research methods that were positive or descriptive in nature were used while others used methods that were normative in nature, describing what ought to exist under certain assumptions.

The use of different assumptions and research techniques was not from a lack of understanding of what was needed in supply response intelligence. Rather, it was due to the realization that all approaches, whether formal or informal, aggregative or disaggregative, positive or normative, are complementary rather than competitive.

In this chapter, (a) these criteria for classifying the research techniques used in estimating supply response are discussed, (b) the theoretical basis of the static supply function is presented, (c) the most frequently used formal research techniques of estimation are discussed, and

and (d) the problem and objectives of this thesis are presented and placed into perspective with the previous work in supply response research.

A. Criteria to Classify the Techniques of Estimating Supply Response

There are three primary criteria under which supply response research techniques have been classified. A brief discussion of these three criteria will help to understand the technique.

1. Formal or informal

Early production economists relied on informal techniques to analyze supply response and other economic problems. They used a blend of observation, comparison, and common sense, drawing conclusions based on what was known to have worked in similar cases.

With the advent of statistical techniques, of a formalized theory of production, and of mathematical programming, the production economist has turned to these more formal research methods. These techniques have been adopted in an effort to reduce the role of "intuitive judgment" and produce more objective estimates of supply response.

Both informal and formal methods are used today to estimate supply response. The principal informal methods in use include producer panels, observation of technological change and informed judgement on certain resources, types of farms, etc. The formal methods in use include statistical analysis of time series data and various types of mathematical programming models.

Even though researchers working on the policy problems of agriculture have turned to more formal analyses such as the interregional competition models and the national model of production response discussed in Chapter I, the policy makers still rely heavily on informal methods of analyses in making their final decisions.

2. Micro or macro

One of the major problems in acquiring useful supply response intelligence is to determine the level of aggregation at which to make empirical estimates. The decision maker is at the micro level, the operator of a firm. His supply response decisions are based on the micro relationships of the theory of the firm and modified by his economic goals, capital position, investment in fixed factors of production, price expectations and risk aversion. The policy maker, on the other hand, needs supply response intelligence at the macro level. This may be at various levels of commodity and geographic aggregation or for the industry as a whole.

In discussing the need to relate and integrate micro and macro supply response analyses, Heady stated that (17, p. 9):

> The crucial supply information leading to improvement in agricultural policies and educational guidance must come in macro form, by important regional and national aggregates. We need to study the relationships and decision processes underlying individual output choices if we are to understand fully supply phenomena. Eventually, the quantities so derived must be aggregated or lead to improved procedures for estimating supply quantities from aggregate data ... micro and macro analyses must be related and integrated to improve knowledge of supply structure and improve forecasts of output and resource use.

Bonnen recognizes the same problem and writes that (4, p. 256):

> In adjustment research, the problem is usually improperly set up to begin with. Often this involves the generally incorrect notion that research formulated at the very low (or micro) level of aggregation can be used directly to illuminate adequately the much higher national or macro level variables of adjustment problems. The reverse also holds. Research done at quite aggregative or macro levels in the economy is rarely ever directly useful in analyses involving micro level variables. Obviously, the problems of adjustment are not confined only to one level of aggregation in the agricultural industry. There is a clear need in adjustment problems to design research which functionally relates the micro level analyses to the macro.

3. Positive or normative

A third criteria for classifying techniques of estimating supply response is to determine whether the method is basically positive or normative.

Positive analysis, also referred to as descriptive or predictive, is an attempt to describe quantitative relationships among variables as they have existed over a period of time.

Techniques of normative analysis are more commonly used to answer the "if-then" type of question, what ought to exist under certain assumptions. For example, a common question of this type is - "If producers want to maximize their profits then what should they produce and what mix of resources should they use."

There is no clear dichotomy between these two classifications. Terms such as "conditionally normative" and "subjective linkage with positive aspects" are found in the literature on supply response. The use of positive analysis, normative analysis, or some mixture of the two depends on the nature and purposes of the supply response estimates desired.

B. The Theoretical Basis of the Static Supply Function

At the heart of supply analysis lies the static production function of the individual firm. If we assume a perfectly competitive firm operating under perfect knowledge with respect to all variables and an operator of that firm with the single objective of profit maximization, the firm's static supply function can be derived directly from the production function.

This can be illustrated by using the simple production function:

$$(1) \quad Y = aX^b$$

where Y is the output and X is an input. The total cost function for the production of good Y would be:

$$(2) \quad TC = k + P_x X$$

where k is a fixed cost and P_x is the unit price of the input X. The profit maximization criterion under perfect competition would be fulfilled if the marginal cost of the output good is equal to the marginal revenue of the output good which under perfect competition is also equal to the unit price of the output good.

$$(3) \quad MC = MR = P_y$$

The static supply function can now be derived by a) expressing the production function (Equation 1) in terms of the input (resulting in Equation 4), b) substituting Equation 4 into Equation 2 to get Equation 5, c) taking the first derivative of Equation 5 to get marginal cost (Equation 6), d) setting the MC equal to the unit price of the output good as shown in Equation 7, and e) express Equation 7 in terms of the output good (Equation 8).

$$(4) \quad X = Y^{\frac{1}{b}} a^{-\frac{1}{b}}$$

$$(5) \quad TC = k + P_x (Y^{\frac{1}{b}} a^{-\frac{1}{b}})$$

$$(6) \quad \frac{dTC}{dY} = P_x b^{-1} Y^{\frac{1}{b}-1} a^{-\frac{1}{b}}$$

$$(7) \quad P_y = P_x b^{-1} Y^{\frac{1}{b}-1} a^{-\frac{1}{b}}$$

$$(8) \quad Y = \left(\frac{a^{\frac{1}{b}} \, b \, P_y}{P_x} \right)^{\frac{b}{1-b}}$$

Since at all points on the static supply function we have the condition that MC = MR, the supply function is precisely the marginal cost curve. The portion of the marginal cost curve actually forming the supply curve for a rational firm is at all rates of output equal to or greater than the rate of output associated with minimum average variable cost.

Problems arise when this simple derivation of the supply function is applied to formulate empirical estimates of supply response. The first is the violation of the original assumptions - firms do not operate under conditions of perfect knowledge nor do they possess a simple objective based only on profit maximization. A second problem is that few firms in agriculture produce single products but rather several products that often are complementary or supplementary over some range. Although it is conceptually possible to derive the supply functions for multiple products from the production function in a manner similar to equations 1-8 above, it is difficult in practice to make an independent measure of common resources used in the production of several or all of the multiple products.

When we attempt to aggregate static supply functions from a multiple of firms to derive empirical supply estimates for the industry we encounter the additional problem of external diseconomies. An external diseconomy would be created when all producers move up their supply curve and increase their output sufficiently to cause the price for an input to be bid up. The increased price of the input results in a higher marginal cost of production to produce a given quantity of output (the MC curve shifts to the left). The shift of the MC curve to the left caused by the increased price of the input prevents us from horizontally summing the supply curves of the firms to obtain the industry curve. Instead, the industry supply curve is somewhat more steeply sloped and somewhat less elastic than it would be in the absence of external diseconomies.

This problem is illustrated in Figure 1. As the price of the output good is increased from P_1 to P_2, the firm will respond by moving along its marginal cost curve, MC_1, from output quantity q_1 to q_3 if there is no change in the price of the input. If the price of the input does increase the firm will move to a point on its new marginal cost curve, MC_2, and its maximum profit output quantity becomes q_2. Thus, the creation of the external diseconomy when all firms in the industry increase their production results in a supply curve such as SS. The relevant firm supply curve to be used for aggregation is the "unmeasured" SS curve rather than

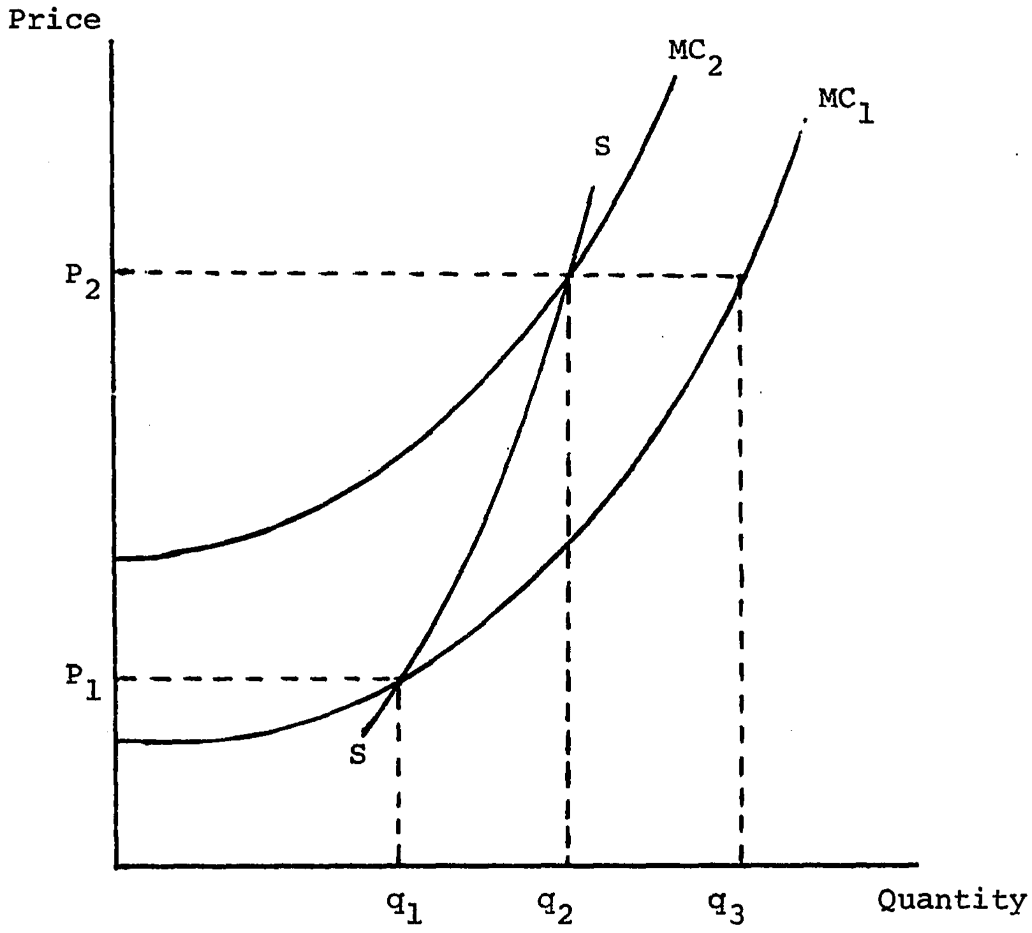

Figure 1. Illustration of the effect of an external pecuniary diseconomy on the product supply function

the "measured" MC_1 function.

C. Techniques Used for Empirical Estimates of Supply Response

A variety of techniques have been used to make empirical estimates of supply response. The greatest emphasis in recent years has been on two formal techniques, linear regression and linear programming, and their variations.

1. Linear regression

To estimate supply response by statistical techniques, researchers have used linear regression models of time-series data. Knight has reviewed some studies that used linear regression models (23, p. 74-104). More recent literature in agriculture economics contain reports of many additional studies in which linear regression models of time-series data were used.

Regression analysis is useful to determine relationships at a relatively high level of aggregation. The magnitudes of the variables dealt with directly in regression analysis are those most useful for making policy decisions.

There is, however, an aggregation problem encountered in regression analysis. Time-series data are generally short in relation to the number of important independent variables postulated to affect the quantity of a commodity supplied. The aggregation problem arises when it is necessary to confine attention to only a few explanatory variables.

Regression analysis is generally classified as a positive method of analysis. The estimated regression equation is descriptive of the quantitative relationships as they have existed over some period of time. The effect each independent variable has on the quantity of the commodity supplied is measured directly in the estimated regression equation. The supply function is estimated when the price of the commodity is included as an independent variable and other independent variables in the equation are interpreted as shifters of this supply function.

The regression analysis may be predictive as well as descriptive if historical conditions continue to exist in the future period of interest - if the exogenous variables can be projected with a significant degree of accuracy. Dummy variables and time trends can be used in the regression equation to measure changes in the structure of agriculture and in technology. As long as these changes are gradual and continue at the historical rate, regression analysis can provide good extrapolations into the future. Distributed lag models, which are a simple way of including the effects of fixed factors of production and the effects of a producer's psychological inertia against change, may also help make regression analysis predictive. Distributed lag models are most useful for commodities with a short production period such as crops. They prove to be less useful when the production period covers several seasons as is the case with many livestock products.

The principal criticism of linear regression as a technique to estimate supply response arises from the inability to measure all of the important exogenous variables under certain conditions. For some of the more important policy questions there are no historical observations of a proposed new policy variable. The effect of the new policy variables cannot be measured in regression models relying on time-series data. Regression models are, therefore, inadequate to answer many important policy questions.

2. Linear programming

Linear programming is also a formal research technique to estimate supply response. It has been used in a wide variety of studies because marginal analysis concepts from the theory of production are included in a linear programming model. These include production functions, production possibility functions, and marginal value products of factors of production. The objective function of a linear programming model is the unidimensional goal commonly assumed in the theory of the firm, profit maximization (or cost minimization).

Linear programming is classified as a normative technique. The profit maximization objective function enables a researcher to describe what production and resource use patterns ought to exist if a producer truly had this single objective. Because it is a normative technique, and because of the "stepped" or discontinuous nature of the solutions to linear programming models, supply functions generated from linear programming models are often referred to in the literature as "synthetic" supply estimates.

The normative nature of supply response functions derived from variable price linear programming models has generally resulted in empirical estimates that have low predictive value. Researchers have not had sufficient information to incorporate restraints in the linear programming models that would suitably modify the assumption that profit maximization is the single goal of the operator of a firm. D. Gale Johnson, however, has been one of a number of researchers who have stated their belief that a consistent theory of supply is provided under the assumption of profit maximization. He goes on to state that (21, p. 547):

> It is not necessary for our purposes that farmers actually maximize profits, but it is important, of course, that reliable predictions can be made by using the assumption of profit maximization.

The normative nature of linear programming models does, however, make this technique useful where time-series regression analysis breaks down. New policy variables can be considered in linear programming models and intelligence can be generated on the effect of the new policy variables. No historical data is necessary since the basic assumption of the normative model, with or without the new policy variable, is profit maximization.

The flexibility of linear programming models is another important reason the technique has been used in studies of supply response. The model may be structured to include resource restraints that depict different degrees of fixity of resources. This makes the technique useful to examine supply response over different economic lengths-of-run. The model may also be structured to conduct an analysis of firms at the micro level or regions at the macro level. Possible levels of aggregation include (a) all farms in a region treated individually, (b) several farms in a region representative of many other farms not appearing in the model, (c) one typical or average farm representing all farms in a region, and (d) a region treated as one large farm.

The supply response studies discussed briefly at the end of Chapter I are examples of the possible variations in linear programming models. The Heady-Egbert model of interregional competition treats each production region as one large farm. With all major producing areas included in the model, normative price-quantity estimates are generated directly for the major crops produced in the United States. The Heady-Egbert type model has been used over a longer length-of-run, five to ten years.

The national model of agricultural production response also treats each region as one large farm. However, each production area is an independent sub-model and aggregate production response is obtained by summation of the results from each of these sub-models. The emphasis is on short-run estimates of production response so the solutions to the sub-models are conditioned with restrictions on the rate of change of quantities produced.

The regional adjustment studies have used the "representative farm" as the unit of analysis. Using a few firms to represent many others not appearing in the model is a method to keep a model to a "manageable" size while simulating the response decisions as being made by the managerial units that actually make them. Another advantage of representative farm models is the flexibility of the model structure to include resource mobility among farms.

The supply response estimates from the regional adjustment studies were of an intermediate-run nature. The estimates of supply response on the representative farms were summed to derive aggregate response functions for states and regions.

D. The Problem and Objectives of this Study

Although a large amount of work has been done to derive empirical estimates of supply response many problems remain. Time-series regression estimates may be both descriptive and predictive if basic structural and technological relationships remain as they were in the past. Regression analysis is inadequate, however, when new policy variables on which there is no historical data are introduced into the system.

Several variations of linear programming analysis have also been used to derive empirical estimates of supply response. This technique embodies the micro relationships found in the theory of production, is flexible for use at different levels of aggregation and different lengths-of-run, and is useful to examine the possible effects of new policy variables. The major problem with supply response estimates generated from linear programming models is that the estimates have had low predictive value.

One additional problem still remaining in estimating supply response is to be able to relate firm and aggregate supply response. Neither regression analysis of time-series data nor linear programming models using different levels of aggregation have proven adequate to handle this problem.

The general objective of this study is to determine if there are improved empirical techniques that can be used to attack some of these problems encountered in making empirical estimates of supply response. Following an examination of the models used and the results of previous supply response studies, the specific problem was narrowed to finding ways to change and modify linear programming models of the type used in the regional adjustment studies, to improve on their predictive value at the firm level and especially at the aggregate level.

1. <u>Analysis of the regional adjustment studies</u>

To review briefly, six regional adjustment studies were conducted as cooperative projects of State Agricultural Experiment Stations and the Farm Production Economics Division of the Economic Research Service, U.S. Department of Agriculture. These projects had as their primary objectives to (a) estimate adjustments needed in resource allocation on farms to maximize profits, (b) estimate regional supply-response, and (c) determine an equilibrium supply-demand condition for a region and then for individual farms.

The principal technique used in these studies was a linear programming approach that Sharples calls a "representative farm aggregation" model (RFA model) (32, p. 354). The general procedure followed in applying this type of model was (a) stratify all farms in a region into groups that are assumed to have similar response patterns, (b) define a representative farm for each stratum, (c) use variable price linear programming to derive supply functions for each representative farm, (d) sum the supply functions to regional aggregates, and (e) adjust the results in order to make predictions or prescriptions.

In discussing the accomplishments and results of the regional adjustment studies, Sharples writes as follows (32, p. 355):

> Much has been gained from the regional adjustment studies. First, but possibly not foremost, were the representative farm adjustment results and the regional results. Second, a data base (budgets, representative farm data, and other quantitative data) was established that is currently being utilized and updated in other research projects. Third, these studies provided graduate training ..., and technical training as well. Many in the profession got their first taste of mathematical programming and electronic data processing via the regional adjustment studies.
>
> And fourth, we learned that the problems connected with the RFA model were more devastating than we had first imagined. The aggregate regional analysis - the justification for having regional projects - was disappointing.

As an example of the disappointing regional aggregate results we can look at the Corn Belt study. Colyer and Irwin authored the publication in which these aggregate results were first presented. They state that (9, p. 62):

> The most significant feature (of the aggregate results) is the large quantities of livestock products - quantities so large that they clearly could not be absorbed by U.S. consumers at any reasonable price level. Hog production for the Region alone at most price levels would be several times the annual average output for the United States in the early 1960's
>
> The quantities of beef cattle also were large ... At all price combinations production of either beef or hogs or both exceeded current production levels. It should be noted further that the region has historically produced only about 1/2 of the U.S. beef, but nearly 4/5 of the pork.

Several authors have discussed reasons why the aggregate results from the regional adjustment studies were disappointing. Stovall considered three sources of error encountered in estimating regional supply functions from independent representative farm linear programming solutions (36, p. 478):

1. Specification error arises because the programming model fails to reflect accurately the conditions actually facing the farm firm for a given length of run. Specification error may include errors in the technical coefficients, the resource restrictions, or product and input prices.

2. Sampling error arises when the distribution of the model's parameters over all firms in the population is not known but is estimated by sampling techniques.

3. Aggregation error as defined by Frick and Andrews is "the difference between the area supply function as developed from the summation of linear programming solutions for each farm in the area and summation from a smaller number of 'typical' or 'benchmark' farms."[1]

Other reasons discussed by researchers for the disappointing results of the regional adjustment studies fall under these three sources of error presented by Stovall. Colyer and Irwin (9) point out the problem of including realistic group restrictions in a model of an individual firm. It is unrealistic not to allow the firm to purchase inputs in any quantity at a constant price of the input. But for the region it is impossible for all firms to purchase all of the inputs they may want at that price. Colyer and Irwin consider this conflict between what an individual firm can do in contrast with what all farms as a group can do to be a specification error.

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[1] For an excellent example of recent work on analyzing the problem of aggregation error, see Miller's unpublished Ph.D. thesis (26).

Sharples, Miller and Day (34) discuss six principal reasons for the problems of the regional adjustment studies. Their first four reasons, (a) failure to consider external effects, (b) failure to meet the defined conditions of internal consistency, (c) the assumed level of applied technology, and (d) assumptions about the cost of production, are all examples of specification error. Aggregation error is the fifth reason discussed by Sharples, Miller and Day.

2. Objectives of this study

The specific objectives of this study are:

a) to develop a supply response model that will functionally relate firm and aggregate supply response.

b) to include in the model some additional methods to reduce specification and aggregation error.

c) to estimate the supply response for pork and beef in the state of Iowa to test the feasibility of the model.

d) to analyze the empirical results obtained as a means of evaluating the proposed methodology, and to draw out economic implications for the area studied.

III. THE CONCEPTUAL MODEL

The conceptual model for this study focuses on three major problems encountered by researchers in making empirical estimates of supply response. The first is to functionally relate firm and aggregate supply response. The second and third are to consider additional ways to reduce specification error and aggregation error in making the supply response estimates.

A. A Method to Functionally Relate Firm and Aggregate Supply Response

The producing unit analyzed in the regional adjustment studies was the representative farm. The estimates of supply response from each farm were summed to acquire state and regional total supply response. This method greatly over estimated the aggregate supply response because the external diseconomies that are created when all producers increase production are not considered.[1] For example, it is reasonable to assume that each farm could hire all of the labor it might need at a constant wage rate, but it is unreasonable to assume that all farms in an area as large as a state can hire all the labor they need without forcing up that wage rate. This

[1]The problem created by external diseconomies when the analyst wants to sum quantities supplied by firms to derive an aggregate supply quantity was discussed in Chapter II.

conflict between what an individual farm can do in contrast with what all farms as a group can do is a source of specification error.

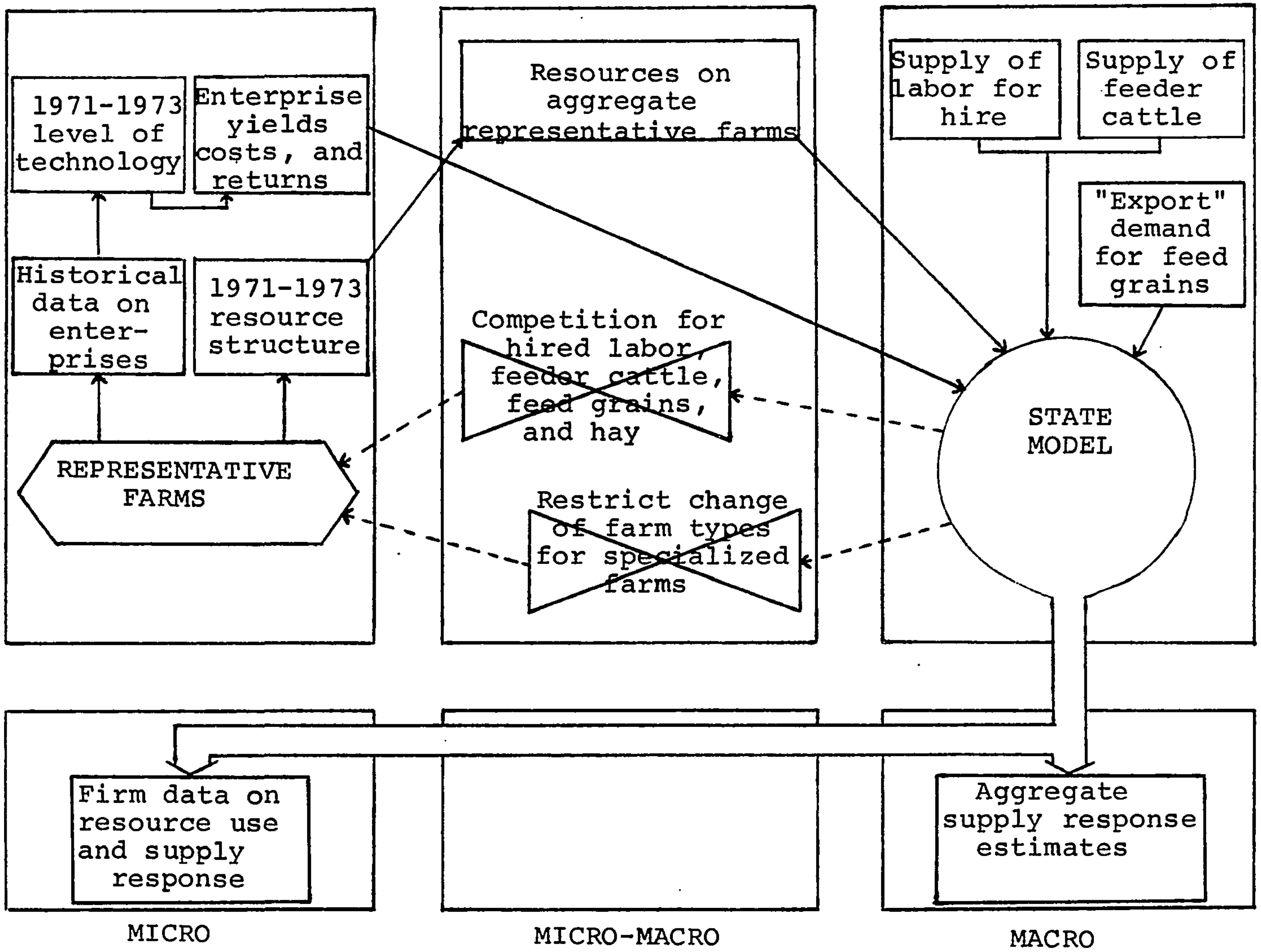
To alleviate this problem it is necessary to consider the possible effect of external diseconomies - to analyze supply response of individual farms in a way that their response is conditioned by the combined actions of all farms. Rather than each representative farm being considered an independent producer, which was the assumption used in the regional adjustment studies, interaction among farms must be allowed for. The model needs to be constructed to allow the firms to compete for inputs that are, in fact, limited to the group of firms. Such a model might logically be called an "interfirm competition" model.

1. Interaction among farms

One obvious way to allow for interaction among farms is to construct a single model for the state or region with each representative farm being a sub-model of this single model. Products or inputs can then be transferred between farms and supplies of inputs that are limited to the group of farms can be endogenously allocated between them (the farms can compete for the limited inputs).

A model of this type is depicted in Figure 2. The representative farm is retained as the basic production unit at the micro level. Information for each representative farm

Figure 2. Conceptual model to functionally relate firm and aggregate supply response


1971-1973 level of technology
Enterprise yields costs, and returns
Historical data on enter-prises
1971-1973 resource structure
REPRESENTATIVE FARMS
Resources on aggregate representative farms
Competition for hired labor, feeder cattle, feed grains, and hay
Restrict change of farm types for specialized farms
Supply of labor for hire
Supply of feeder cattle
"Export" demand for feed grains
STATE MODEL
Firm data on resource use and supply response
Aggregate supply response estimates
MICRO
MICRO-MACRO
MACRO

is entered into the single state model which is the macro unit of analysis. Supplies of inputs such as labor for hire and feeder cattle are limited at the macro level and these macro limits will condition the supply response of the representative farms as they are forced to compete for these inputs. Farms may also transfer feed grains and hay between them and in a sense compete for these intermediate products which are used as inputs for livestock production. Finally, the producers within the state can be forced to compete for feed grains with producers outside of the state by including an exogenous demand for feed grains by these out-of-state producers.

One additional element is needed in the micro-macro link up to allow the interaction among farms. A mechanical aggregation problem is encountered if the number of farms depicted by a representative farm differs from the number of farms depicted by another representative farm with which it has interaction. For example, let farm A be representative of 1000 farms and farm B be representative of 2000 farms. If the representative farms are used in the state model, we may find that farm A sells 100 bushels of corn to farm B. However, this would not be consistent with the model specification. The 1000 farms represented by A would be selling 100,000 bushels of corn while the 2000 farms represented by B would be purchasing 200,000 bushels.

This mechanical aggregation problem can be avoided by weighting the resources on each representative farm by the appropriate number of farms being represented. These aggregate levels of resources are then used in the state model. The unit of analysis in this case is more aggregate than an individual farm, but such a procedure does not prevent the estimation of resource use and supply response at the representative farm level. This data is available by dividing the results for each "aggregated representative farm" by the number of farms being represented.

2. Factor supply functions

The assumed nature or form of factor supply functions is an important variable in determining the empirical form of product supply functions. For an individual firm operating in a market environment such as perfect competition, the factor supply functions can be assumed to be perfectly elastic. If the supply of a factor is limited to a small group of firms, it might be assumed that the factor supply function is perfectly elastic up to the limiting point where it becomes a perfectly inelastic function. The limited quantity of the factor might even be exogeneously allocated to the firms by the researcher through some criteria such as historical proportions.

For a large group of firms, the factor supply function will be upward sloping over some range, the range being dependent on the economic length-of-run assumed and the type of factor under consideration. As the firms bid for more of the factor they force an increase in the price of the factor, creating an external diseconomy.

Recognizing the possible existence of these external diseconomies is a necessary part of a model designed to functionally relate firm and aggregate supply response. The aggregate supplies of labor for hire and feeder cattle shown in Figure 2 should thus be entered in the state model as upward sloping factor supply functions.

B. Methods to Reduce Specification Error

Included in the sources of specification error are lack of internal consistency, errors in technical coefficients, errors in resource restrictions, and inaccurate levels of product or input prices. Methods to minimize these sources of specification error are included in the conceptual model shown in Figure 2.

1. Enterprise yields, costs and returns

Most of the sources of specification error listed above enter into the construction of enterprise budgets. To reduce the effect of these sources of error, the enterprise budgets should be constructed to represent the production functions and prices that are expected to exist on each representative farm during the calendar period the model is to represent.

Internal consistency would not be a problem if the production function was linear throughout all possible size levels of an enterprise. However, empirical investigation suggests that many production functions in agriculture are curvilinear, and the problem of internal consistency becomes more acute as the production function for an enterprise becomes more nonlinear.

An estimated supply quantity is consistent with the assumed production function if the assumption on enterprise size used to construct the budget for that commodity is not violated at the level of estimated supply. For example, if the assumed size of a beef feeding enterprise used in constructing the budget for a representative farm is 50-75 head, the estimated supply quantity should also be 50-75 head if this estimate is to be consistent with the assumed production function.

If the empirical supply response estimates generated from the state model are reasonably close to historical levels of supply quantities, historical data on the size of enterprises found on each representative farm will conceptually be useful in reducing problems of internal consistency. This is one of the reasons why historical data on the enterprises found on the representative farms has been included in the conceptual model depicted in Figure 2.

The budgets should also measure the difference in production functions found on farms because of topography of land, size of machinery and equipment, and degree of specialization in certain enterprises. Finally, consideration must be given to the rate of change in technology when the budgets are constructed. The level of technology that is expected to exist during the calendar period the model is to represent should be used in the enterprise budgets.

The prices to be used in the model for inputs and products also need to be considered when attempting to minimize specification error. First, they should be the prices that producers expect to exist and on which they base their supply response decisions during the calendar period the model represents. Price forecasting is an imperfect art but another consideration helps to compensate for the inability to make perfect price forecasts. This would be to have all prices in proper relative relationship to other prices even though the absolute price levels may not have been forecasted accurately.

To maintain the proper relative price relationships is especially important in two elements of the conceptual model shown in Figure 2. Historical price trends as well as price relationships must be considered when the price ranges are chosen for the upward sloping portions of the input supply functions to be used for hired labor and for feeder cattle. Then, as the prices of some products are varied to generate empirical estimates of supply response, the relative price relationships must be kept consistent at all of the product price combinations.

2. Resource structure

To help minimize specification error, the resource structure on each representative farm must represent the same calendar period the production functions represent. The ratios of labor to land, labor to capital and capital to land should be consistent with the assumed production functions for each representative farm. More specifically, the size of farms, the percent of land that is cropland, the percent of cropland that can be used for row crops, and the amount of capital available to carry on the farming operation should be consistent with the calender period the model represents. Also, quantities of labor need to be properly specified for calendar periods as well as what quantity of this labor is available from operators, from family members, from workers that can be hired on an annual basis, and from workers available only for seasonal work.

C. Methods to Reduce Aggregation Error

Aggregation error may arise when supply response estimates from representative farms are used to estimate the area supply response rather than using a supply response estimate from each farm. The primary method employed by researchers to minimize aggregation error in studies where they used representative farm analysis is to stratify farms into groups that will have similar response patterns. The population of farms might be stratified by area, size and type of farm because these are criteria for classification readily found in published data sources and because these are criteria that are expected to influence the optimal farm plan.

The results of the Corn Belt regional adjustment study showed, however, that the type of farm may not be a useful criteria for stratification. The resource restraints and production activities included on the representative farms did not capture the elements that cause farmers to specialize in the production of certain products. The reasons for specialization may more nearly be personal preference of the operator and limits in his managerial capacity.

Two elements of the conceptual model shown in Figure 2 are included to capture the reasons, whatever they may be, why some farmers specialize in grain production, some specialize in hog production, etc. The first is the feed back from the state model to the representative farms which requires that the specialized farms not change to another type. Empirical data from the Census of Agriculture, from farm record summaries and other sources show that specialization in farming has been increasing in recent years. Because specialization in production generally requires investment in specialized equipment or facilities as well as specialized knowledge, it is not reasonable to allow all farms to change in the short-run or intermediate-run to completely different products that would result in a different type classification for the farm.

The historical data on enterprises can also be used to capture further the existing specialization in production and help reduce aggregation error. This data shows that not all of the farms produce some of each product. The minor or non-existent enterprises for each representative farm can be deleted from the list of enterprises to be produced on that farm.

D. The Conceptual Model in a Linear Programming Framework

Linear programming was chosen as the mathematical model to be used in this study. The various aspects of the conceptual model can all be included in the framework for a linear programming model.

The representative farms are the basic unit of analysis in the linear programming model. To avoid the mechanical aggregation problem caused by different numbers of farms being depicted by each representative farm, the resources on each representative farm are "weighted" to form an "aggregated representative farm." These production units are entered into the state model as sub-matricies of the state matrix. These sub-matricies form a diagonal in the aggregate matrix as shown in Figure 3. The subscript "m" is used to index the number of farms represented by each representative farm and "n" is used to identify the representative farms.

The resource vector for each aggregated representative farm contains the data on what quantities of resources are available on each production unit. The production functions assumed to exist on each representative farm become the activities of the programming model. Each representative farm that is specialized in the production of certain products can be restrained to sell only those products that will maintain the farm type definition.

Transfer rows for intermediate products and supplies of inputs limited to a group of producers in part of the state form a second part of the model. These matrix rows along with some transfer activities form the "area" portion of the aggregate matrix shown in Figure 3.

Finally, the "state" portion of the aggregate matrix allows for transfer of intermediate products between areas and the purchase and distribution of the inputs that are limited at the state level of aggregation.

1. The mathematical model

Mathematically, the linear programming model can be expressed as follows:

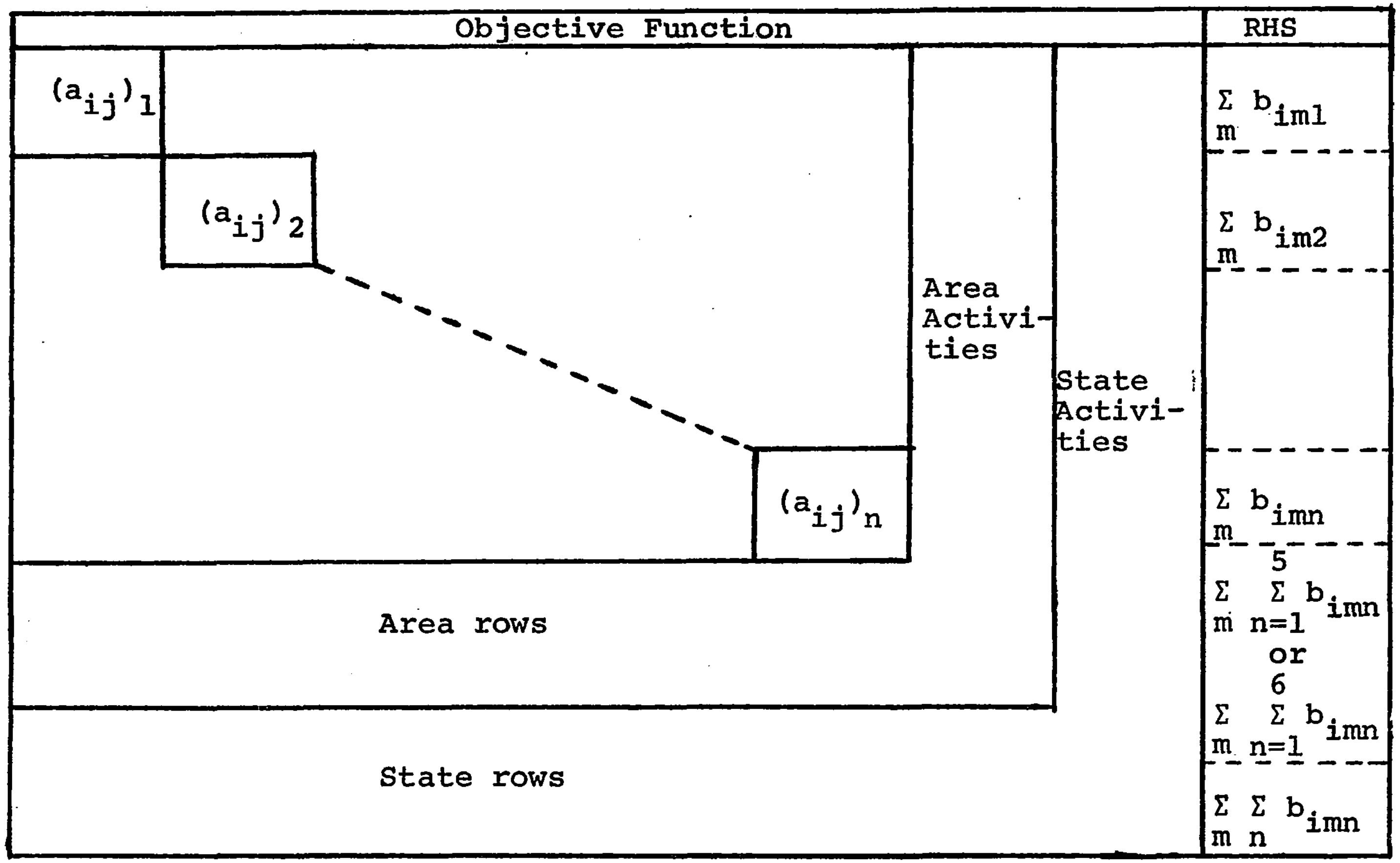


Figure 3. Schematic of the linear programming model

$$\text{Maximize } Z = \sum_m \sum_n \sum_f P_f \, Q_{fmn} + \sum_m \sum_n \sum_g P_g^s \, Q_{gmn}^s$$

$$- \sum_m \sum_n \sum_g P_g^b \, Q_{gmn}^b - \sum_m \sum_n X_j^t \, R_{jmn}^t$$

subject to:

$$\sum_m \sum_f a_{ifmn} \, Q_{fmn} + \sum_m \sum_g a_{igmn} \, Q_{gmn}^s \leq \sum_m b_{imn}$$

$$\sum_m \sum_f a_{jfmn} \, Q_{fmn} + \sum_m \sum_g a_{jgmn} \, Q_{gmn}^s$$

$$- \sum_m R_{jmn}^t \leq \sum_m \sum_n b_{jmn}$$

$$\sum_m \sum_n Q_{gmn}^s - \sum_m \sum_n Q_{gmn}^b \geq 0 \text{ or } = 0$$

$$Q_f, \, Q_g \geq 0$$

$m = 1, \ldots M$; M = the number of producing units represented by representative farm n

$n = 1, \ldots N$; N = the number of representative farms

$f = 1, \ldots F$; F = the number of final products produced

$g = 1, \ldots G$; G = the number of intermediate products produced

$i = 1, \ldots I$; I = the number of resources that are limited on a farm independent of other producing units

$j = 1, \ldots J$; J = the number of resources that are limited to the aggregate of producing units

Z = net returns above variable costs

P_f= the unit price of a final product (or cost of carrying on activity f)

Q_{fmn} = the quantity of a final product f sold by producing units m represented by farm n (or level of activity f carried on)

P_g^s = the farm selling price of a unit of intermediate product g

Q_{gmn}^s = the quantity of intermediate product g sold by producing units m represented by farm n

P_g^b = the farm delivered price of a unit of intermediate product g

Q_{gmn}^b = the quantity of intermediate product g purchased by producing units m represented by farm n

X_j^t = the unit price of resource j that is endogenously allocated within the model because it is not limited to an individual producing unit but is limited in the total amount available to the aggregate of producing units, mn

R^{t}_{jmn} = the quantity of resource j purchased by producing units m represented by farm n

a_{ifmn} = the amount of resource i that is used by producing units m represented by farm n in carrying on a unit of activity f

a_{igmn} = the amount of resource i that is used by producing units m represented by farm n in carrying on a unit of activity g

a_{jfmn} = the amount of resource j that is used by producing units m represented by farm n in carrying on a unit of activity f

a_{jgmn} = the amount of resource j that is used by producing units m represented by farm n in carrying on a unit of activity g

b_{imn} = the beginning endowment of resource i found on producing units m represented by farm n

b_{jmn} = the beginning endowment of resource j available to the aggregate of producing units, mn

2. The optimal solution

An important theoretical question arises when interpreting the optimal solution from an interfirm competition model. What does the optimal solution represent? Is it an optimal solution for each of the producing units or is it only an optimal solution for the "industry" with some producing units operating in an unprofitable manner as long as industry profits are maximized?

Certainly, the optimal solution values for a representative farm are not the same as would be obtained by programming the farm separately with the same linear programming coefficients. The assumptions of interaction among farms and possible externalities result in a different optimal solution than would be obtained in the absence of these assumptions. The economic environment in which the representative farms operate is more nearly simulated, however, by including these assumptions.

The question of whether the optimal solution is a perfectly competitive equilibrium for each farm or is only optimal for the aggregate of farms revolves around the common rows in the model. These rows allow farms to interact with each other - to buy and sell intermediate products and to compete for the limited supplies of hired labor and feeder cattle. Because of the interaction with other farms, a single farm may not be able to, say, hire all of the labor it desires to hire at the assumed hired labor price. The difference between the amount of labor the farm would hire if it was programmed independently and what it is able to hire due to interaction with other farms represents the extent to which the interfirm competition model does not achieve a perfectly competitive equilibrium at the programmed factor prices. This situation is shown graphically in Figure 5.

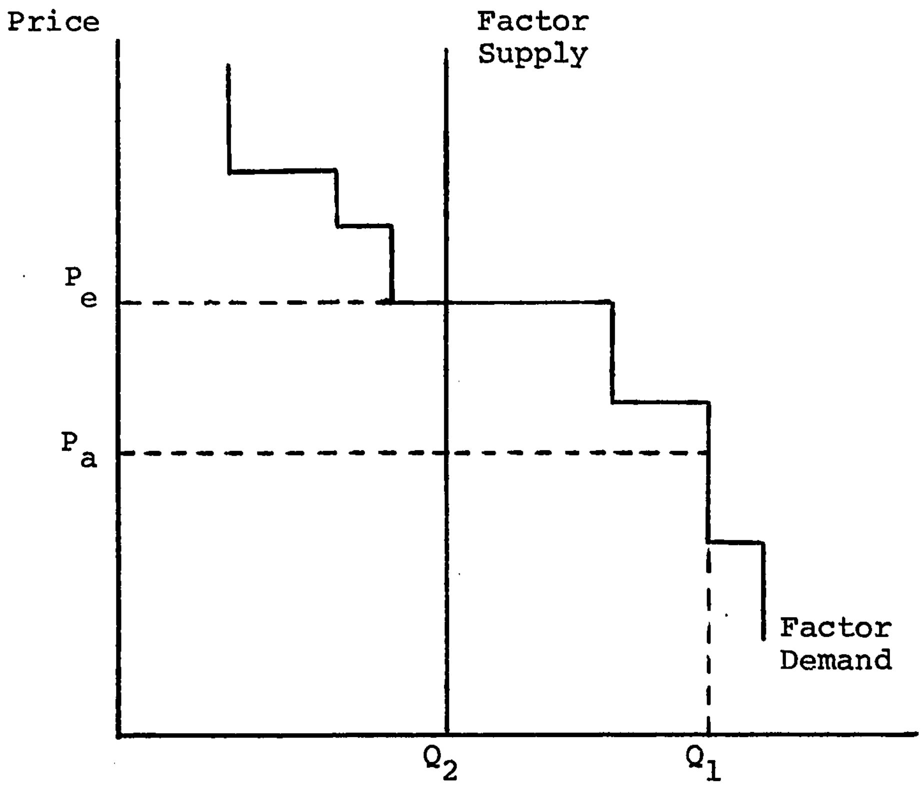


Figure 4. Market for a factor that is in limited supply to the aggregate of firms

P_a represents the observed market price used as the programming price for hired labor. The point where this price cuts the aggregate factor demand curve for labor results in the total quantity demanded, Q_1. This quantity is considerably in excess of the labor supply of Q_2. However, there is a higher price, an equilibrium price P_e, where the quantity demanded by all of the individual farms and the quantity supplied would approach each other. At this price, the optimal solution to the interfirm competition model would approach the sum of the optimal solutions for the individual farms programmed separately. The sum of the independent solutions would, in fact, be equal to the solution from the interfirm competition model if the factor demand function was smooth rather than a stepped function.

The equilibrium price for each of the common rows is found in the dual to the optimal solution for the interfirm competition model. Each of the common rows is included in the model to allow the firms to compete for the supply of a factor of production or an intermediate product that is also used as a factor of production. The dual gives the imputed values for each of these factors and thus gives the equilibrium factor price for each of the common rows.

If the primal problem is written in matrix notation as:

$$\max Z = C'X$$

subject to:

$$AX = B$$

$$X \geq 0$$

then the dual of the problem is:

$$\min \alpha = B'V$$

subject to:

$$A'V = C$$

$$V \geq 0$$

Since the statements of the primal and dual problems include the slack variables we have in the primal problem m equations of the type

$$a_{11} X_1 + a_{12} X_2 + \ldots + a_{1n} X_n + U_1 = b_1$$

and n equations in the dual problem of the type:

$$a_{11} V_1 + a_{21} V_2 + \ldots + a_{m1} V_m - L_1 = C_1$$

From the optimal solutions to the primal and dual problems we have the conditions that:

$X_j L_j = 0$ for each output product j

$U_i V_i = 0$ for each input i

In fact, any pair of feasible solutions to the primal and dual problems which satisfy this requirement must be optimal.

Taking a closer look at the second condition, $U_i V_i = 0$

for each input i, we find this has a straight forward interpretation. If the quantity of a resource, U_i, is restrictive ($U_i = 0$) the marginal value product of the resource is some positive value ($V_i > 0$). Alternatively, if the resource is not scarce ($U_i > 0$) then its marginal value product will be equal to zero ($V_i = 0$) and the condition of $U_i V_i = 0$ will still hold.

The problem of finding the equilibrium price for the common rows or resources being competed for is thus a problem of choosing a value of V_i which is the equilibrium price. If all farms are competing for the resource and the resource is in short supply for the aggregate of farms, each farm that wants to purchase some of the resource will have a value for V_i that is greater than zero. The specific farm with the highest value of V_i would be the internally generated equilibrium price for that factor of production.

If similar V_i values are chosen to give the equilibrium prices for all of the common rows, these internally generated factor prices can be used in programming each farm separately and the sum of the independent solutions will approach the solution from the interfirm competition model.

IV. THE EMPIRICAL MODEL

The purpose of the present chapter is to provide empirical substance to the conceptual model outlined above. The focus of the chapter is on the population studied; the constraints, activities, and prices of the model; and the determination of endogenous factor supply functions.

A. The Population Studied and Stratification Procedures

The state of Iowa was chosen as the population to be studied. The state is a major producer of feed grains and red meats and also contributes significantly to the total United States production of soybeans, hay, milk and poultry. In 1968 Iowa ranked as the number one state in hog production, producing one-fourth of all the hogs raised in the U.S. Iowa also ranked first in the number of cattle on feed and second in size of inventory of all cattle and calves. The contribution by the state in crop production was twenty-one percent of all corn for grain, sixteen percent of all soybeans, twelve percent of all oats and six percent of all hay. The state thus ranked first in the production of corn for grain, second in soybean production, second in oat production and fourth in hay production.

This major contribution from Iowa farms to total agriculture production makes it an important area to study. The empirical estimates of supply response in pork and beef production in Iowa are major components of the total supply response in the U.S.

Although other states in the North Central also produce significant quantities of pork and beef, an area as big as a state is large enough to test the conceptual model. Using several states or a region for a study area would make the model much larger than is needed to test the proposed methodology.

Finally, because Iowa was included in the Corn Belt regional adjustment study, there are empirical estimates of aggregate supply response already made for the state. The results of this study can be compared with those estimates and the procedures used in this study can be more thoroughly evaluated.

To select the representative farms from the population a three step stratification procedure was used. The stratification scheme was chosen to minimize aggregation error within the constraints of time and cost to construct and utilize the model. In a study on aggregation error, Miller found that some aggregation error was introduced when he reduced the number of representative farms for Iowa from thirty-six to ten, to three, and finally to one (26, p. 164). Miller found that larger amounts of aggregation error are found in livestock production estimates than in crop production estimates. In summarizing his work on stratification procedures, Miller states (26, p. 165):

> The key idea is that the individual farms be stratified to account for (1) differences in their coefficient matricies and (2) differences in their expected response patterns on adjustments.

and also (26, p. 166):

> The final selection of representative farms must be made considering (1) the additional research costs of including more representative farms versus (2) larger amounts of aggregation error. The problem is basically one of deciding for each research project how much of the aggregation error it is economically feasible to eliminate.

The first level of stratification used in this study was to divide the state into five areas based on general soil types. This area division is shown in Figure 5.

Within each area the farms were divided into those smaller than 260 acres and those 260 acres or larger. This division resulted in about one-half of the total farmland in Iowa being placed in each size category, based on data from the 1964 Census of Agriculture. The dividing point is also roughly consistent with the different complements of machinery that are assumed to be found on large and small farms in the state, and with differences in land-labor ratios.

The third characteristic used in the stratification procedure was the type of farm. Survey data taken on Iowa farms in 1964 and in 1966 were available to determine the type classification. This was part of the data gathered in the ERS Pesticide Use Surveys taken throughout the U.S. in 1964

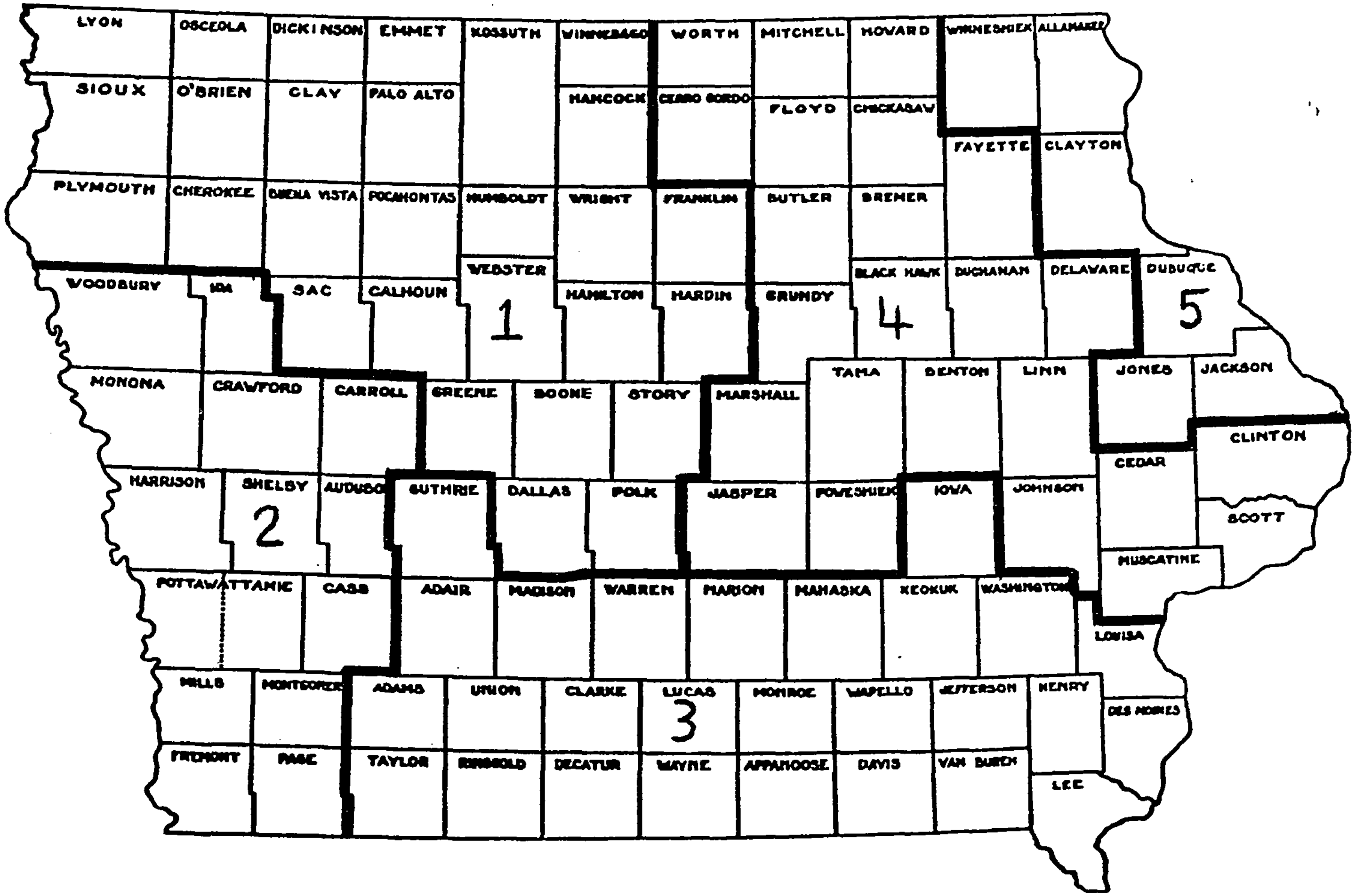


Figure 5. Stratified production areas in Iowa

and again in 1966.

Four types of specialized farms were considered first. A cash grain or dairy representative farm was defined in each area-size cell if fourteen percent or more of the farms in the area-size cell derived over half of their gross sales from grain or dairy. A specialized beef or specialized hog representative farm was defined in each area-size cell if ten percent or more of the farms in the area-size cell received over seventy percent of their gross sales from beef or hogs.

The general representative farm in each area-size cell includes all of the farms not already included in the specialized farms defined for that area-size cell. These were predominantly livestock farms that did not meet the definition of a specialized beef or a specialized hog farm.

Table 1 lists the twenty-seven representative farms that resulted from the stratification procedure and gives their stratification characteristics.[1] Each area has either five or six representative farms. There are fourteen small farms and thirteen large farms; seven cash grain farms, three dairy farms, four beef farms, three hog farms, and ten general farms. The representative farm identification number shown in the table is used as a reference in later discussion.

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[1]For a detailed description of the procedure used to estimate the number of farms being represented by each representative farm see Appendix A.

Table 1. Representative farms and their stratification characteristics

Representative farm number	Stratification characteristics		
	Area	Size	Type
1	1	small	cash grain
2	1	small	general
3	1	large	cash grain
4	1	large	beef
5	1	large	general
6	2	small	beef
7	2	small	general
8	2	large	cash grain
9	2	large	beef
10	2	large	general
11	3	small	cash grain
12	3	small	hog
13	3	small	general
14	3	large	cash grain
15	3	large	general
16	4	small	cash grain
17	4	small	dairy
18	4	small	hog
19	4	small	general
20	4	large	cash grain
21	4	large	general
22	5	small	dairy
23	5	small	hog
24	5	small	general
25	5	large	dairy
26	5	large	beef
27	5	large	general

B. Model Constraints and Activities

The linear programming matrix for an interfirm competition model contains rows and columns for the aggregated representative farms, for the areas, and for the state (see Figure 3). The twenty-seven sub-models for the aggregated representative farms are nearly all the same in their basic structure of rows and columns. Some differences do occur because the representative farms don't all produce the same products. The five sub-models for the areas all have an identical structure.

1. Matrix rows for the representative farms

The identification of the matrix rows used for each representative farm is shown in Table 2. The type of constraint and unit of measure for each equation are also listed. A brief description of the purpose of each equation will be presented here. Further information on the matrix rows, the quantity of each resource, and the methods used to estimate these quantities are presented in Appendix B.

The first six equations of the representative farm submodel are the labor resources by calendar periods. The resource vector values for these rows are the hours of labor available from the farm operator or his family in each period. If additional labor is hired it is added to three values and labor needed for production activities is subtracted from

Table 2. Matrix rows for each representative farm

Row number	Type of constraint[a]	Identification	Unit of measure
FR01	L	Total labor	Hour
FR02	L	December-March labor	"
FR03	L	April-May labor	"
FR04	L	June-July labor	"
FR05	L	August-September labor	"
FR06	L	October-November labor	"
FR07	L	Cropland	Acre
FR08	L	Non-cropland pasture	"
FR09	L	Row-crop land	"
FR10	L	Corn base	"
FR11	L	Conservation base accounting	"
FR12	L	Nurse crop accounting	"
FR13	L	Distribute corn equivalent	Bushel
FR14	L	Distribute Government price support acres	Acre
FR15	L	Distribute Government diverted acres	"
FR16	L	Distribute rotation meadow	"
FR17	L	Distribute hay	Ton
FR18	L	Distribute hay equivalents	"

[a]The types of constraints are L = less than or equal to and G = greater than or equal to.

Table 2 (Continued)

Row number	Type of constraint[a]	Identification	Unit of measure
FR19	L	Hog farrowing facilities, first and third quarter	Litter
FR20	L	Hog farrowing facilities, second and fourth quarter	"
FR21[b]	L	Dairy facilities	Cow
FR22	L	Distribute pork	Cwt. live wt.
FR23[c]	L	Distribute beef	Cwt. live wt.
FR24	L	Operating capital	Dollar
FR25	G	Cash accounting	"
FR26	G	Returns over variable cost accounting	"
FR27[d]	L	Gross sales accounting	"

[b]Row 21 is found only on representative farms 17, 22 and 25.

[c]Row 23 is not found on representative farms 17 and 22.

[d]Row 27 is not found on representative farms 2,5,7, 10,13,15,19,21,24, and 27.

these values.

Rows 7-10 are land constraints. The beginning resource vector value of row 7 is reduced by any production activity using cropland. The resource vector value for row 8 is the acres of non-cropland pasture found on each farm. This quantity is added to if rotation meadow is needed for pasture and reduced by any production activity requiring pasture. Row 9 is a limit on the total acreage of row crops that can be grown on the farm while row 10 serves as a limit on the acres of corn that can be grown on a farm whether any or all participate in the Government feed grain program.

Row 11 is needed because of the Government feed grain program and has a zero value in the resource vector. This value is increased by any production activity that meets the definition of conservation base for the feed grain program and reduced by each feed grain production activity that is participating in the Government program.

The nurse crop accounting row, number 12, forces some consistency in the cropping pattern. It has a zero value in the resource vector and any production activity that can serve as a nurse crop to meadow seedings adds to the beginning value. Those production activities that require a nurse crop subtract from the beginning value.

The next six rows, number 13 through 18, serve as distribution or transfer rows in the matrix. Rows 19 and 20 limit the number of litters of hogs that can be farrowed in any calendar quarter and row 21 is used on dairy farms to limit the number of dairy cows to the capacity of the dairy facilities. Rows 22 and 23 are additional transfer rows.

The operating capital row, number 24, serves as the source of funds for production activities. The initial resource vector value is the operator's supply of operating capital plus the amount he can obtain by borrowing operating capital. As these funds are needed they are transferred to the cash accounting row. Row 25 then serves as the accounting row for cash needed by production activities and cash supplied from the operating capital row.

Row 26 serves as a minimum income constraint. It requires the production activities to produce sufficient returns over their variable cost of production to pay for family living and other fixed costs encountered on each farm.

Finally, row 27 acts to restrain the production activities on each farm to those that will allow the farm type classification to remain unchanged. This row is not needed, therefore, on those farms that are classified as "general" representative farms.

2. Matrix rows for the areas

There are five area sub-models used in the matrix. Each row of an area sub-model is a common equation to all of the representative farms in that area. The matrix rows used in each area are identified in Table 3.

The first row in each area sub-model is a transfer row for corn equivalents. Row 2 is a balancing row that requires all hay sold by farms in the area to be purchased by other farms in the same area.

Table 3. Matrix rows for each area

Row number	Type of constraint[a]	Identification	Unit of measure
AR01	L	Distribute corn equivalents	Bushel
AR02	E	Hay balance	Ton
AR03	L	Area supply of seasonal labor for hire in the April-May calendar period	Hour
AR04	L	Area supply of season labor for hire in the June-July calendar period	"
AR05	L	Area supply of seasonal labor for hire in the August-September calendar period	"
AR06	L	Area supply of seasonal labor for hire in the October-November calendar period	"
AR07	L	Count the hundred weight of liveweight of fed beef sold from the area	Cwt. of live wt.
AR08	L	Count the hundred weight of liveweight of pork sold from the area	Cwt. of live wt.
AR09	L	Count the acres of corn produced in the area	Acre
AR10	L	Count the acres of land in the area that is diverted from the production of feed grains under the Government feed grain program	"

[a]The types of constraints are L = less than or equal to and E = equal to.

The next four rows are the supply of labor available for seasonal hire in four different calendar periods. This supply of labor for seasonal hire is limited to the area and not considered to be mobile across the state.

The last four rows of the area sub-model count the quantities of various products produced in the area. These are accumulation rows that provide a partial summary of the solution to the linear programming model without further aggregation.

3. Matrix rows for the state

Each row in the state portion of the matrix is a common equation for all representative farms and areas in the state. The matrix rows used for the state portion of the matrix are identified in Table 4.

The objective function is the first row common to all representative farms and areas. The second row is another transfer row for corn equivalents.

The next fifteen rows allow the use of a factor supply function for hired labor.[1] Row 3 is the supply of full-time labor for hire. This equation is common to all farms because full-time labor for hire is assumed to be mobile around the state. Rows 4, 5, 6 and 7 limit the total amount of seasonal

[1]A more complete explanation of this portion of the matrix is given later in this chapter when the endogenous factor supply functions are discussed.

Table 4. Matrix rows for the state

Row number	Type of constraint[a]	Identification	Unit of measure
SR01	N	Objective function	Dollar
SR02	L	Distribute corn equivalents	Bushel
SR03	E	Supply of full-time hired labor	Hour
SR04	L	Available seasonal labor for hire in April-May	"
SR05	L	Available seasonal labor for hire in June-July	"
SR06	L	Available seasonal labor for hire in August-September	"
SR07	L	Available seasonal labor for hire in October-November	"
SR08	L	Distribute hired labor	"
SR09	L	Maximum quantity of labor for hire at low wage rate	"
SR10	L	Maximum quantity of labor for hire at first artificial wage rate	"
SR11	L	Maximum quantity of labor for hire at second artificial wage rate	"
SR12	L	Maximum quantity of labor for hire at third artificial wage rate	"
SR13	L	Maximum quantity of labor for hire at fourth artificial wage rate	"
SR14	L	Maximum quantity of labor for hire at fifth artificial wage rate	"
SR15	L	Maximum quantity of labor for hire at sixth artificial wage rate	"

[a]The types of constraints are N = not constraining, L = less than or equal to, and E = equal to.

Table 4 (Continued)

Row number	Type of constraint[a]	Identification	Unit of measure
SR16	L	Maximum quantity of labor for hire at seventh artificial wage rate	"
SR17	L	Maximum quantity of labor for hire at eighth artificial wage rate	"
SR18	E	Supply of native feeder calves	Head
SR19	E	Supply of feeder calves	"
SR20	E	Supply of feeder yearlings	"
SR21	E	Distribute beef feeders at price one	Head
SR22	E	Distribute beef feeders at price two	"
SR23	E	Distribute beef feeders at price three	"
SR24	E	Distribute beef feeders at price four	"
SR25	E	Distribute beef feeders at price five	"
SR26	E	Distribute beef feeders at price six	"
SR27	L	Maximum quantity of beef feeders for purchase at low price	"
SR28	L	Maximum quantity of beef feeders for purchase at first artificial price	"
SR29	L	Maximum quantity of beef feeders for purchase at second artificial price	"
SR30	L	Maximum quantity of beef feeders for purchase at third artificial price	"

Table 4 (Continued)

Row number	Type of constraint[a]	Identification	Unit of measure
SR31	L	Maximum quantity of beef feeders for purchase at fourth artificial price	Head
SR32	L	Maximum quantity of beef feeders for purchase at fifth artificial price	"
SR33	L	Count the bushels of corn sold off of the farm where produced	Bushel
SR34	L	Count the bushels of corn produced	"
SR35	L	Count the bushels of soybeans produced	"
SR36	L	Count the bushels of oats produced	"
SR37	L	Count the hundred weight of live weight of beef sold	Cwt. of live wt.
SR38	L	Count the hundred weight of live weight of pork sold	Cwt. of live wt.
SR39	L	Count the number of beef feeders fed	Head
SR40	L	Count the number of beef cows	"
SR41	L	Count the number of dairy cows	"
SR42	L	Count the number of litters of hogs	Litter
SR43	L	Maximum quantity of corn equivalents that can be exported out of the state	Bushel
SR44	L	Distribute investment capital	Dollar

labor available for hire by four calendar periods. Row 8 is a transfer row for all hired labor. As labor is hired at successively higher prices, it is put into this row and in turn is hired out as full-time hired labor or as seasonal labor by periods. Rows 9 through 17 are the maximum quantities of all types of labor available for hire at nine discontinuous points on the factor supply function.

State rows 18 through 33 are needed to incorporate the factor supply function for beef feeders.[1] The native feeder calf row, number 18, accumulates the beef calves produced within the state before they are transferred to the factor supply function. The rows for supplies of feeder calves and feeder yearlings, rows 19 and 20, serve as transfer rows to distribute purchased beef feeders to the beef feeding activities. Rows 21 through 26 take native calves and feeders shipped into the state and make them available for purchasing at six discontinuous points on the factor supply function. These rows serve as a means to limit the price received for native calves to the same price paid for feeder animals. Finally, rows 27 through 33 are the maximum quantities of feeder cattle that can be purchased at each of the six discontinuous points on the factor supply function.

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[1]A more complete explanation of this portion of the matrix is given later in this chapter when the endogenous factor supply functions are discussed.

Ten rows to provide summary totals of various products produced in the state are included in the state portion of the matrix. These are rows 33 through 42. Row 43 limits the quantity of corn equivalents that can be exported from the state and the last row, number 44, serves as a means to charge a higher interest rate on capital to be invested in livestock facilities.

4. <u>Matrix columns for the representative farms</u>

The columns included in the matrix for each representative farm are very similar. Minor differences do occur because some farms do not have a beef cow herd, a dairy herd or feed beef cattle.

The columns or activities for each representative farm are grouped into market activities, crop production activities, hog production and facility investment activities, beef production activities and dairy production and facility investment activities. Table 5 shows the identification of the matrix columns for the aggregated representative farm production units. More detailed information on the activities, the construction of the activity budgets, the budget information and an example matrix of a representative farm submodel are contained in Appendix C.

The first five columns for each representative farm submodel are market activities that are variable priced to generate the supply response estimates for pork and beef.

Table 5. Matrix columns for each representative farm

Column number	Identification	Unit of measure
FC01[a]	Sell pork	Cwt.
FC02[a]	Sell beef	"
FC03[a]	Sell corn equivalents	Bushel
FC04[a]	Buy corn equivalents from other farms in the area	"
FC05[a]	Buy corn equivalents from other farms in the state	"
FC06	"Sell" acres earning a feed grain program price support payment	Acre
FC07	"Sell" acres earning a feed grain program diversion payment	"
FC08	Sell hay	Ton
FC09	Buy hay	"
FC10	Hire full-time labor	Hour
FC11	Hire seasonal labor for April-May	"
FC12	Hire seasonal labor for June-July	"
FC13	Hire seasonal labor for August-September	"
FC14	Hire seasonal labor for October-November	"
FC15	Obtain operating capital	Dollar
FC16	Corn grain for maximum participation in the feed grain program	Acre
FC17	Corn grain for minimum participation in the feed grain program	"
FC18	Corn grain	"

[a]These activities were variable priced to generate the supply response estimates.

Table 5 (Continued)

Column number	Identification	Unit of measure
FC19	Corn silage for maximum participation in the feed grain program	"
FC20	Corn silage for minimum participation in the feed grain program	"
FC21	Corn silage	"
FC22	Soybeans	"
FC23	Oats	"
FC24	Rotation meadow	Acre
FC25	Harvest hay	Ton
FC26	Transfer rotation meadow to non-cropland pasture equivalents	Acre
FC27	Transfer hay to hay equivalents	Ton
FC28	Farrow hogs in February and August	2 litters
FC29	Farrow hogs in May and November	" "
FC30	Farrow hogs in June	1 litter
FC31	Invest in hog farrowing facilities	Litter
FC32[b]	Beef cow herd	Head
FC33[c]	Feed beef calves, not pastured	"
FC34[c]	Feed beef calves, pastured	"
FC35[c]	Feed beef yearlings, purchased in November, not pastured	"

[b]Column 32 is not found on representative farms 1, 3, 16, 17, 20, 22 and 25.

[c]Columns 33-37 are not found on representative farms 11, 17 and 22.

Table 5 (Continued)

Column number	Identification	Unit of measure
FC36[c]	Feed beef yearlings, purchased in April, not pastured	Head
FC37[c]	Feed beef yearlings, purchased in April, pastured	"
FC38[d]	Dairy cow herd	"
FC39[d]	Invest in dairy facilities	"

[d]Columns 38-39 are found only on representative farms 17, 22 and 25.

These activities were contained in each representative farm sub-model to allow the proper sales information to be entered into the "returns over variable cost accounting" and "gross sales accounting" rows for each farm.

Columns 6-15 are additional market activities. The Government payments earned by participating in the feed grain program are acquired in columns 6 and 7. Columns 8 and 9 allow the farm to sell or buy hay. These activities are subject to the constraint that other farms in the same area must buy or sell this hay so no excess hay is available for export from the area. That is, the factor market for hay is considered to be a closed or local market within the area.

Column 10 allows the purchase of full-time labor. As each hour is purchased it provides part of that hour of labor to each of the calendar periods. Columns 11-14 are included for hiring seasonal labor for a single calendar period.

The activity to obtain operating capital, column 15, is given this name rather than "borrowing operating capital" because the restraint on operating capital includes both equity capital available for operating and the capacity to borrow funds. Thus, all operating capital used must realize a return at least as great as the assumed rate of interest.

Six corn production activities are included on each farm, columns 16-21. The corn grain or corn silage activity for maximum participation in the Government feed grain program is one-half acre of corn and one-half acre of diverted land. The activities for minimum participation are eight-tenths of an acre of corn and two-tenths of an acre of diversion. Each of these activities use an acre of cropland, an acre of row-crop land and an acre of the allotted corn base for a farm. Although an individual farm must either participate in the feed grain program at a given percentage rate or not participate at all, an aggregate of farms can have some corn land participating and some not participating. The limits are all farms participating at the maximum which would mean all of the corn being produced in the activities that are one-half corn and one-half diversion and no farms participating which would result in all of the corn being produced in activities 18 and 21. The other intermediate activities for minimum participation in the feed grain program are included because of the nature of the payment structure of the Government program.

Columns 22-25 are additional crop production activities. The acre of "standing meadow" produced in activity 24 can either be harvested as hay by activity 25 or transferred to pasture by activity 26. Column 27 is another transfer activity to make hay available for feeding.

Three hog producing activities are included in each representative farm sub-model. A combination of activities 28 and 29 can be used as a multiple farrowing activity. Column 31 allows the purchase of additional hog farrowing facilities. One-third of the cost of a litter-space is added to the beginning resource vector value for operating capital and the balance has to come from the original amount of operating capital. All of the capital invested in additional hog facilities has to earn a twenty percent return before the investment can be made. Finally, the cost of additional facilities on specialized hog farms is greater than for other farms because more mechanization is assumed for the specialized farms.

A beef cow herd is included on many of the representative farms by activity number 32. Five alternative beef feeding activities are depicted by columns 33-37. Ninety percent of an estimated purchase price is considered to be mortgageable property so this value is added to the beginning resource vector value for operating capital.

The dairy production activity and the activity for investment in additional dairy facilities, columns 38 and 39 are included only on the three specialized dairy farms.

5. Matrix columns for the areas

Only one column is included for each area. This is a transfer activity to transfer corn equivalents between the area and the state. Table 6 identifies the area activity along with the state activities.

6. Matrix columns for the state

Almost all of the state columns are needed to allow the endogenous factor supply functions for hired labor and feeder cattle to be included in the model. A more detailed explanation of these stepped input supply functions is given in the last part of this chapter.

The first nine columns in the state portion of the matrix allow labor to be hired at nine different points on the factor supply curve. As labor is purchased it becomes available for hiring as full-time hired labor, column 10, or for hiring as seasonal labor in each of four calendar periods through columns 11-14. As an hour of full-time labor is hired it is available to any farm in the state. When an hour of seasonal labor is hired only a portion of that hour is available to the farms in each area. Thus, the

Table 6. Matrix columns for the areas and for the state

Column number	Identification	Unit of measure
	AREA	
AC01[a]	Transfer corn equivalents	Bushel
	STATE	
SC01	Hire labor at the lowest wage rate	Hour
SC02	Hire labor at the first artificial wage rate	"
SC03	Hire labor at the second artificial wage rate	"
SC04	Hire labor at the third artificial wage rate	"
SC05	Hire labor at the fourth artificial wage rate	"
SC06	Hire labor at the fifth artificial wage rate	"
SC07	Hire labor at the sixth artificial wage rate	"
SC08	Hire labor at the seventh artificial wage rate	"
SC09	Hire labor at the eighth artificial wage rate	"
SC10	Hire full-time labor	"
SC11	Hire seasonal labor for the April-May calendar period	"
SC12	Hire seasonal labor for the June-July calendar period	"
SC13	Hire seasonal labor for the August-September calendar period	"
SC14	Hire seasonal labor for the October-November calendar period	"
SC15	Sell native beef calves at the lowest price	Head
SC16	Sell native beef calves at the second price	"

[a]Column AC01 appears in each area sub-model.

Table 6 (Continued)

Column number	Identification	Unit of measure
SC17	Sell native beef calves at the third price	Head
SC18	Sell native beef calves at the fourth price	"
SC19	Sell native beef calves at the fifth price	"
SC20	Sell native beef calves at the highest price	"
SC21	Import beef feeders at the lowest price	"
SC22	Import beef feeders at the first artificial price	"
SC23	Import beef feeders at the second artificial price	"
SC24	Import beef feeders at the third artificial price	"
SC25	Import beef feeders at the fourth artificial price	"
SC26	Import beef feeders at the fifth artificial price	"
SC27	Buy beef feeders at the lowest price	"
SC28	Buy beef feeders at the first artificial price	"
SC29	Buy beef feeders at the second artificial price	"
SC30	Buy beef feeders at the third artificial price	"
SC31	Buy beef feeders at the fourth artificial price	"
SC32	Buy beef feeders at the fifth artificial price	"
SC33	Export corn equivalents	Bushel
SC34	Impose an additional charge for capital invested in hog facilities	Dollar
RHS	Resource vector	-

seasonal labor is limited to each area, and not considered to be mobile around the state.

State columns 15-20 sell the calves produced by beef cow herds in the state at the six price levels used to depict the factor supply function for feeder cattle. The native beef calves are sold in these activities rather than directly by the beef cow herd activities on each farm to facilitate the requirement that the native calves cannot be sold for a higher price than the price paid to purchase feeder calves.

To provide the additional feeder cattle that may be needed at each of the points on the factor supply function, columns 21-26 import feeder cattle into the state. Finally, columns 27-32 are the activities that purchase feeder cattle at the six points on the factor supply function and make these feeder cattle available to the beef feeding activities found on each farm.

The last two columns of the state portion of the matrix allow the export of corn from the state and impose an additional charge on capital to be used for investment in additional hog farrowing facilities.

C. Prices for the Variable Priced Products

Another set of data needed to give empirical content to the model is the set of prices to use in generating the supply response estimates. These would be prices for corn, pork and beef.

One of the requirements to reduce specification error discussed in the chapter on the conceptual model was to maintain relative price relationships at all combinations of product prices that are consistent with expectations. For this study, the relative product price relationships are considered to be consistent with expectations if they do not exceed the bounds of historical price relationships. The relevant product price relationships for the variable priced activities are the pork-corn price relationship, the beef-corn price relationship and the beef-pork price relationship.

Historical data for 1957-1969 was used to provide a time series for the corn price and for each of the relevant price relationships. This data is shown in Table 7. The average historical price of corn was used as the medium price expectation for corn and this average price plus or minus 1.5 times the standard deviation of the corn price series provided prices for the high and low price expectations for corn. This method resulted in high and low expected prices for corn that bounded the historical price series.

The price relationship series for pork-corn, beef-corn, and beef-pork were used to construct the product prices for pork and beef. The data series for the pork-corn and beef-corn relationship are bounded by the mean of the series plus or minus 1.5 times the standard deviation of the series.

Table 7. Corn price and pork-corn, beef-corn and beef-pork price relationships for 1957-1969

Year	Price of corn[a] ($/bu.)	Price relationships		
		pork: corn[b]	beef: corn[c]	beef: pork[d]
1957	1.10	16.2:1	18.5:1	1.142:1
1958	.97	20.5:1	22.2:1	1.247:1
1959	1.01	13.9:1	23.0:1	1.790:1
1960	.94	16.9:1	23.0:1	1.497:1
1961	.96	17.5:1	22.2:1	1.339.1
1962	.96	16.9:1	24.7:1	1.481:1
1963	1.06	14.0:1	19.3:1	1.473:1
1964	1.08	13.7:1	18.6:1	1.404:1
1965	1.13	18.5:1	20.3:1	1.097:1
1966	1.19	19.3:1	19.6:1	1.049:1
1967	1.13	16.8:1	20.7:1	1.267:1
1968	1.01	18.5:1	24.9:1	1.348:1
1969	1.08	21.2:1	25.8:1	1.213:1
Mean	1.05	17.2:1	21.8:1	1.334:1
Standard deviation	.08	2.4	2.5	.2

[a]Annual average price of corn for Iowa as compiled by the Statistical Reporting Service, U.S. Department of Agriculture.

[b]Pork-corn price relationship for Iowa as compiled by the Statistical Reporting Service, U.S. Department of Agriculture.

[c]Chicago basis beef steer-corn price relationship as compiled by the Statistical Reporting Service, U.S. Department of Agriculture.

[d]Compiled from annual average cattle and pork prices for Iowa that are compiled by the Statistical Reporting Service, U.S. Department of Agriculture.

Thus a low, medium and high pork-corn or beef-corn price relationship was generated by using the mean of each series plus or minus 1.5 times the standard deviation of each series. These low, medium and high pork-corn and beef-corn relationships were multiplied by each of the three corn prices with the result being low, medium and high pork and beef prices at each price of corn that were consistent with historical pork-corn and beef-corn price relationships.

There were two problems, however, with this set of product prices. First, the price relationships were too similar. For example, at each corn price the high pork prices all have the same relative relationship to the corn price. An increased number of dissimilar price relationships would provide more intelligence on the nature of the supply response function if these varying relationships are still consistent.

The second problem encountered with the pork and beef prices when they were generated from the pork-corn and beef-corn price relationships was the inconsistency between the beef and pork price. At each price of corn the high pork price was well above the low beef price while the historical data series showed this to be an inconsistent relationship.

To solve these two problems it was necessary to narrow the range of price relationships considered at each price of corn and also to vary these price relationships. The procedure followed was to divide the range of the pork-corn and beef-corn relationships into sixths. Then the upper two-thirds of the range in relationships was assumed to correspond with the low price for corn, the middle two-thirds was assumed to correspond with the medium price for corn and the lower two-thirds of the range of price relationships was assumed to correspond with the high price of corn. The resulting prices and price relationships are shown in Table 8.

Columns four and five of Table 8 show that of the nine pork-corn or beef-corn price relationships, seven of each are unique quantities. It is also apparent that all of the pork-corn relationship (from 13.6:1 to 20.8:1) and all of the beef-corn relationship (from 18.0:1 to 25.4:1) is examined as the three corn prices are used. Of the nine beef-pork price relationships at each corn price, all are consistent except the lowest one.

D. The Endogenous Factor Supply Functions

One of the specific objectives of this study is to functionally relate firm and aggregate supply response. Previous studies of supply response have generally concentrated on only one level of aggregation. When an attempt was made in the regional adjustment studies to construct aggregate supply response estimates by summing the supply response estimates from independent production units the

Table 8. Product prices and price relationships for the variable priced activities

Product prices			Price relationships		
Corn ($/bu.)	Pork ($/cwt.)	Beef[a] ($/cwt.)	Pork: corn	Beef: corn[a]	Beef: pork[b]
.93	14.88	19.03	16.0:1	20.5:1	.984:1
	17.11	21.32	18.4:1	22.9:1	1.246:1
	19.34	23.60	20.8:1	25.4:1	1.586:1
1.05	15.54	20.21	14.8:1	19.2:1	.982:1
	18.06	22.79	17.2:1	21.7:1	1.262:1
	20.58	25.35	19.6:1	24.1:1	1.631:1
1.17	15.91	21.07	13.6:1	18.0:1	.979:1
	18.72	23.95	16.0:1	20.5:1	1.279:1
	21.53	26.83	18.4:1	22.9:1	1.686:1

[a]The beef prices shown are a mixed price for steers and heifers. The corresponding steer price would make the range on the beef-corn relationship 18.1:1 to 25.5:1.

[b]For each price of corn there actually are nine beef-pork price relationships. The three relationships shown are the lowest, the medium and the highest of the nine relationships.

aggregate results were very unsatisfactory. An empirical method is needed that will preserve the supply response and resource use information at the firm level and will also provide empirically useful supply response estimates at the aggregate level.

In the discussion of the conceptual model the argument was put forth that interdependencies between farms and possible external pecuniary diseconomies need to be considered in a model that functionally relates firm and aggregage supply response. This section is concerned with these aspects of the empirical model.

1. Farm interdependencies for feed grains and hay

Two of the products produced by each production unit are feed grains (corn grain and oats) and hay. These are intermediate products which are also used as inputs for livestock production. As a product these items may be in excess supply on some farms, especially the specialized cash grain farms. As a factor of production these items may be in short supply on some farms, in particular those that specialize in livestock production. Thus, two of the interdependencies among farms needed in the empirical model are the transfers between farms for feed grains and hay.

The internally generated supply functions for feed grains and hay are first perfectly elastic and then become perfectly inelastic. This type of function does not consider the possibility of external diseconomies but does limit the total quantities of feed grains and hay available to the aggregate of farms. Therefore, the problem of large quantities of corn being imported into Iowa, which was one of the results of the aggregate analysis from the Corn Belt regional adjustment study, is avoided. Including an activity in the model to allow corn to be exported from the state is an additional step toward reality since Iowa has historically been a net exporter of feed grains.

2. The factor supply function for hired labor

The hired labor supply function was assumed to be perfectly elastic for each independent representative farm used in the regional adjustment studies. This was a reasonable assumption when the unit of analyses was the firm. We know from other reported research, however, that the supply curve of labor available for hire to an aggregate area is relatively inelastic in the short-run (38). One of the techniques included in a model to functionally relate firm and aggregate supply response must therefore be a way to incorporate this relatively inelastic factor supply function into the model. The production units can then be allowed to hire out of the common pool of labor available for hiring by the aggregate of farms.

One method to limit the amount of labor that can be hired by the aggregate of farms is to include a single constraint in the model. The total hours of labor for hire would be a single value in the resource vector. However, it is possible to introduce the phenomenon of external pecuniary diseconomies for the firm by using a different method to limit the amount of labor that can be hired by the aggregate of firms. This would be to include a supply function for hired labor in the model rather than just one point on the function.

Incorporating a factor supply function for hired labor in the model involves three major analytical steps. A matrix structure must be chosen that will incorporate the factor supply function, the function must be estimated and the function must be partitioned to represent the distinct types of labor included in the function.

a. <u>A matrix structure to incorporate an upward sloping factor supply function</u> Given an empirical model that includes twenty-seven firms operating in a competitive market, all quantities of a homogenous resource will be purchased at the same price. To include a supply function for this homogeneous resource directly in a linear programming model would produce different results, however. The programming model would choose to hire the least expensive units of the resource first and additional unit would not be purchased unless it can be profitably employed at the margin. If this additional unit is available to the model only at an increased supply price, the programming model will purchase this unit if it is profitable at the margin but will pay the increased cost only for this additional unit.

The problem of incorporating the factor supply function in the model is thus a problem of pricing the additional units purchased such that the same price is paid for all units purchased. This can be accomplished by calculating the total cost which must be paid for the additional units of the factor if the factor market is to be competitive. This total cost consists of two parts: (1) the cost of the additional unit purchased at the increased price, and (2) a "surcharge" on the additional unit to make the price of previously purchased units the same as the price for this additional unit.

It is impossible to consider all points on a continuous factor supply function in a linear programming model. It is necessary to choose only a few points of the function to include in the model so it will be a "manageable" and "computable" model. The factor supply function thus becomes a stepped or discontinuous function.

The unit cost of the resource at each segment or step of this supply function can be calculated as follows:

1. The unit cost for the resource in segment one is

$$C_1 = \frac{P_1Q_1}{Q_1} = P_1$$

2. The unit cost for the resource in segment two is

$$C_2 = \frac{P_2Q_2 - P_1Q_1}{Q_2 - Q_1}$$

3. The unit cost for the resource in segment n is

$$C_n = \frac{P_nQ_n - P_{n-1}Q_{n-1}}{Q_n - Q_{n-1}}$$

When C_1, C_2, ..., C_n are used as the objective function values for a unit of labor at each segment of the factor supply function the same price will be paid for each unit of the resource.

b. Estimation of the factor supply function for hired labor Empirical estimates of the regional supply of hired labor were published by Tyrchniewicz and Schuh in 1966 (38). They used a distributed lag model to estimate the short-run and long-run supply relation and also estimated the demand relation for purposes of identification. The supply equation expresses hired farm employment as a function of (38, p. 541) (a) real wages of hired farm labor, (b) a measure of the income earned in nonagricultural employment, (c) the amount of unemployment in the economy (which affects the availability of alternative income opportunities), and (d) the size of the civilian labor force.

One possible way, then, to estimate a hired labor supply function for Iowa is to utilize the supply elasticity estimates from the Tyrchniewicz and Schuh study and apply them to Iowa data. If we assume the labor market conditions are reasonably homogeneous throughout each region they used in their study, the elasticity estimtaes for the West North Central region can be applied to Iowa.

To use a supply elasticity estimate to trace out the supply function for Iowa requires a point estimate on which to position the function. This point estimate can be made using data on employment and wage rates for hired farm labor in Iowa. The resulting function is then a hired agricultural labor supply function for Iowa.

The base point estimate is derived by projecting historical data on the quantity and price of hired labor in Iowa to 1972. The base quantity estimate is

$$Q = \sum_{i=1}^{12} N_i H_i \qquad i=1,2,\ldots,12$$

where Q is the estimated hours of labor available for hire in 1972, N_i is the 1972 projection from a linear time series equation for the number of all hired farm workers in month i, and H_i is the 1965-69 average number of hours of work by all hired farm workers in month i.

The base price estimate is derived by projecting time series data with a double-log function.

$$\log Y = a + b \log X + e$$

The dependent variable Y is the annual average composite wage rate per hour for hired workers in Iowa and the independent variable X is time, 1964 to 1969.

The supply elasticity estimate is derived from the short-run elasticity and the elasticity of adjustment estimated by Tyrchniewicz and Schuh for the West North Central region. When the distributed lag equation form is used, the long-run elasticity estimate can be derived by

$$LRE = \frac{SRE}{1 - EA}$$

where LRE is the long-run elasticity, SRE is the short-run elasticity, and EA is the elasticity of adjustment derived from the coefficient for the lagged dependent variable. This is the limiting quantity from a geometric progression so a three year elasticity estimate for the model can be derived from the first three elements of the progression. This estimate, based on the Tyrchniewicz and Schuh data, is .494 for the West North Central region.

The estimated supply curve for hired labor in Iowa is shown in Table 9. The base point estimate is Q = 35,637,000 hours and P = \$1.80 per hour. The upward sloping portion of the curve is assumed to be between the \$1.40 and \$3.00 wage rates. Below \$1.40 the curve is assumed to be perfectly elastic and above \$3.00 it is assumed to be perfectly inelastic. Also shown in Table 9 are the total wage bill at each step of the supply curve used in the model and the calculated programming cost (C_j value) for each step.

c. Division of the hired labor supply function Two distinct types of labor are employed in agriculture: full-time and seasonal. The employment of seasonal labor greatly increases the number of workers on farms in the summer months. For example, in 1969 the average number of hired workers on Iowa farms in the months of December-March was 10,500 while seasonal labor increased this to an average of 50,000 for June-August. This is not, however, a five-fold increase in the hours of labor hired because seasonal workers may only

Table 9. Estimated price-quantity loci for Iowa hired farm labor curve and estimated programming costs

Wage rate	Quantity	Total wage bill	Programming costs
($/hr)	(1000 hrs.)	($1,000)	(C_j)
1.40	31,041	43,457	1.40
1.60	33,435	53,496	4.19
1.80	35,637	64,147	4.84
2.00	37,593	75,186	5.64
2.20	39,450	86,790	6.25
2.40	41,221	98,930	6.85
2.60	42,919	111,589	7.46
2.80	44,550	124,740	8.06
3.00	46,123	138,369	8.66

work a few hours in a month.

Data gathered in the 1964 and 1966 ERS Pesticide Use Surveys shows that of 563,221 hours of hired labor employed on the surveyed farms, 420,479 hours or 74.66 percent of all labor hired was from full-time workers. This estimate of not more than .3394 of an hour of seasonal labor employed for each hour of full-time labor employed is used to divide the supply function for all hired labor into full-time and seasonal labor. This division is imposed on the model by requiring that one hour of full-time labor must be hired by the farms to make .3394 of an hour of seasonal labor available for hiring.

d. The matrix structure for hired labor Table 10 is a partition of the linear programming matrix showing the rows and columns needed to include the estimated hired labor supply function. Only one farm and one area are included in the illustration.

If the farmer needs to hire labor he can acquire a portion of an hour of labor in each calendar period by hiring an hour of full-time labor, activity FC10. This hour of labor is obtained from the state pool of full-time labor, SR03, which in turn is acquired by hiring labor at one of the steps on the labor supply function (SC01 - SC09 and SR09 - SR17) and making it available as full-time labor in activity SC10. When an hour of full-time labor is hired an additional .3394 of an hour becomes available for hire as seasonal labor in four periods, SR04 - SR07. Since the seasonal labor is assumed to be immobile (it is limited to each area), only a portion of the seasonal labor available at the state level is available to each area, AR03-AR06. Thus, the farm competes at the state level for full-time hired labor but only with other farms in the area for seasonal labor.

Data from the 1964 and 1966 ERS Pesticide Use Surveys were used to apportion the hour of full-time labor to periods and to apportion the quantity of seasonal labor for each period to the areas.

Table 10. Partition of the linear programming matrix to illustrate the inclusion of the hired labor supply function

	FC10[a]	FC11	FC12	FC13	FC14	SC01	SC02	SC03	SC04
SR01[b]						1.40	4.19	4.84	5.64
FR01	-1.0	-1.0	-1.0	-1.0	-1.0				
FR02	-0.2586								
FR03	-0.1863	-1.0							
FR04	-0.1965		-1.0						
FR05	-0.1815			-1.0					
FR06	-0.1771				-1.0				
AR03		1.0							
AR04			1.0						
AR05				1.0					
AR06					1.0				
SR03	1.0								
SR04									
SR05									
SR06									
SR07									
SR08						-1.0	-1.0	-1.0	-1.0
SR09						1.0			
SR10							1.0		
SR11								1.0	
SR12									1.0
SR13									
SR14									
SR15									
SR16									
SR17									

[a]Identification of the column names are found in Tables 5 and 6.

[b]Identification of the row names are found in Tables 2, 3 and 4.

SC05	SC06	SC07	SC08	SC09	SC10	SC11	SC12	SC13	SC14
6.25	6.85	7.46	8.06	8.66					
						-0.3944			
							-0.2960		
								-0.3256	
									-0.5177
					-1.0				
					-0.0694	1.0			
					-0.1510		1.0		
					-0.0707			1.0	
					-0.0483				1.0
-1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0	1.0	1.0	1.0
1.0									
	1.0								
		1.0							
			1.0						
				1.0					

3. <u>The factor supply function for feeder cattle</u>

Another factor of production that is assumed to be limited to the aggregate of farms in this model is feeder cattle. Since Iowa has been the leading state in numbers of cattle on feed for many years, the demand for feeders by Iowa producers must have some effect on the price they will have to pay for this resource. An upward sloping factor supply function again is needed to represent this situation.

a. <u>Estimation of the factor supply function for feeder cattle</u> A double-log function was used to estimate the supply of feeder cattle for Iowa. The equation is:

$$\log Y = a + b_1 \log X_1 + b_2 \log X_2 + e$$

where Y = the number of feeder cattle imported into Iowa each year plus the number raised in Iowa and not needed for replacement stock

X_1 = the annual average price at Omaha for feeder cattle (assumed to be a mixture of calves and yearlings, heifers and steers)

X_2 = the number of beef cows in the U.S. on January 1 of each year

The *a priori* constraints placed on the parameters were $b_1 > 0$ and $b_2 > 0$.

This equation was fit to data for the period 1957 through 1968.

The estimated equation is:

$$\log \hat{Y} = -1.41262 + \underset{(.14153)}{.22077} \log X_1 + \underset{(.10745)}{1.04215} \log X_2$$

$$R^2 = .913$$

The numbers in the parentheses are the standard errors of the coefficients.

All of the regression coefficients had the expected signs and the Durbin-Watson test for serial correlation in the residuals indicates that serial correlation was not present. The estimated equation is significant at the one percent level with a standard error of the estimate of .02150.

Additional independent variables that measured the number of yearlings not on feed on January 1, the percent of the cattle on feed in the U.S. on January 1 that were on feed in Iowa, and a time variable were not included in the estimated equation. The equation was also estimated in the distributed lag form but this was rejected because of an incorrect sign for the regression coefficient of the lagged dependent variable.

The short-run elasticity estimate from the fitted equation is .22077 and the shifter of supply is the number of beef cows in the U.S. The price range over which the feeder cattle supply function is assumed to be upward sloping is $20 per hundred weight to $35 per hundred weight. This price range is consistent with the range of slaughter cattle prices used in the model. To obtain a three year elasticity estimate the number of beef cows in the U.S. was projected to 1971 and 1973 with a linear time series equation (R^2 = .982). These estimates of the number of beef cows, variable X_2, were then used to construct the short-run supply curves for feeder cattle in Iowa in 1971 and 1973. The three year elasticity for feeder cattle was assumed to be the lowest arc elasticity between the 1971 and 1973 estimated short-run supply curves. This estimate over the $20 to $35 price range is .2689.

Table 11 shows the points from the estimated supply function that were used in the model. The programming costs are also shown.

b. <u>The matrix structure for feeder cattle</u> A major problem was encountered in structuring the linear programming matrix to include the upward sloping supply function for feeder cattle. Some of the feeder cattle are produced in the model and these will be sold in the solution at the highest price on the supply function, $35 per hundred-weight. The matrix must be structured to prevent a higher price received for produced feeders than is paid for purchased feeders.

Table 12 is a partition of the linear programming matrix showing the rows and columns needed to include the estimated feeder cattle supply function. Only one farm is included in the illustration and rows for labor, corn, etc., needed by the production activities are not included nor are the fed beef transfer row or the selling activity for fed beef.

The feeder cattle that are produced in the state (FC32) are placed into a state pool of native feeders, SR18. They are sold at one of the six price levels, SC15-SC20, but forced to be sold at the lowest price first because SR21-SR26 are equalities and the buying price dominates the selling price since the majority of feeders are imported. Native feeders can be sold at a higher price only if a higher price is paid for purchased feeder cattle.

Table 11. Estimated price-quantity loci for Iowa feeder cattle curve and estimated programming costs

Price	Quantity	Total cost	Programming costs
($/cwt.)	(1000 head)	($1000)	(C_j=$/head)
20.00	4,590.0	492,048	107.20
23.00	4,775.2	588,687	521.81
26.00	4,960.4	691,281	553.96
29.00	5,145.6	799,832	586.12
32.00	5,330.8	914,339	618.28
35.00	5,516.0	1,034,802	650.44

Table 12. Partition of the linear programming matrix to illustrate the inclusion of the feeder cattle supply function

	FC32[a]	FC33	FC34	FC35	FC36	FC37	SC15	SC16	SC17	SC18	SC19
SR01[b]	-43.31	-23.72	-22.72	-23.25	-21.21	-18.15	96.03	110.45	124.82	139.23	153.64
SR18	-.72						1.0	1.0	1.0		1.0
SR19		1.0	1.0								
SR20				1.0	1.0	1.0					
SR21							-1.0				
SR22								-1.0			
SR23									-1.0		
SR24										-1.0	
SR25											-1.0
SR26											
SR27											
SR28											
SR29											
SR30											
SR31											
SR32											

[a]Identification of the column names are found in Tables 5 and 6.

[b]Identification of the row names are found in Tables 2, 3 and 4.

Table 12 (Continued)

	SC20	SC21	SC22	SC23	SC24	SC25	SC26	SC27	SC28	SC29	SC30	SC31	SC32
SR01[b]	168.06							-107.20	-521.81	-553.96	-586.12	-618.28	-650.44
SR18	1.0												
SR19								-.6	-.6	-.6	-.6	-.6	-.6
SR20								-.4	-.4	-.4	-.4	-.4	-.4
SR21		-1.0						1.0					
SR22			-1.0						1.0				
SR23				-1.0						1.0			
SR24					-1.0						1.0		
SR25	-1.0					-1.0						1.0	
SR26		-1.0					-1.0						1.0
SR27								1.0					
SR28									1.0				
SR29										1.0			
SR30											1.0		
SR31												1.0	
SR32													1.0

When feeders are needed for the beef feeding activities, FC33-FC37, they are obtained by purchasing them at one of the steps on the supply function, SC27-SC32, and transferred to the farms by rows SR19 and SR20. It was necessary to assume the purchased feeders are a fixed ratio of calves and yearlings to have all feeders purchased at the same step on the supply function. If one matrix structure is used for calves and another for yearlings, the calves may be purchased at a different price level than is paid for yearlings.

V. ANALYSIS OF EMPIRICAL RESULTS

One of the specific objectives of this study is to estimate the supply response for pork and beef in Iowa. This chapter is concerned with these empirical estimates of supply response for pork and beef and other information on resource use that is given in the solutions to the model. Chapter VI will be a discussion of the usefulness and the limitations of the methodology of the model, based upon these estimates of supply response. Additional empirical information from the model is presented in Appendix D.

Only three preselected points on the supply functions for pork and beef are estimated so the empirical estimates are discontinuous price-quantity loci of the supply functions. The product prices to be used to estimate the supply response for pork and beef were discussed in Chapter IV. Using all of the price combinations shown in Table 8 would result in three supply functions for pork at each price of corn or a total of nine functions for pork. A similar number of functions would be estimated for beef. Because of the cost of computing the model, the number of solutions was decreased to provide only three functions for pork and three for beef. The information contained in the resulting fifteen solutions is sufficient to evaluate the feasibility of the model. The entire ranges of pork-corn and beef-corn price ratios were investigated in the fifteen solutions.

The empirical results discussed below reflect the general assumptions used in the model. The assumptions that should be remembered when interpreting the empirical results are:

1. All producers have perfect knowledge and the single objective of profit maximization.
2. All producers act and respond in unison. They are all assumed to have the same economic length-of-run and to respond to price stimuli in perfect unison and as if all price changes are permanent.
3. The demand for products is perfectly elastic. Iowa farmers can sell all they can produce at a given price.
4. The land, labor and capital resources are those that will be found on Iowa farms in the 1971-73 calendar period.
5. The production functions are the ones that will be found on different sizes and types of farms in different areas of Iowa in the 1971-73 calendar period.
6. Feed grains can be transferred between farms within the state or exported from the state but none can be imported into the state.
7. Hay can be transferred between farms within each area but none can be purchased or sold outside of

each area.

8. The supply of hired farm labor is a function of the wage rate. All farms in the state compete for the supply of full-time hired labor and the farms in each area compete for the supply of seasonal hired labor.
9. The supply of feeder cattle is a function of the price of feeder cattle. All farms in the state compete for this supply of feeder cattle.
10. All specialized farms will continue to produce those products that will maintain their type of farm classification.
11. The production on all farms must return enough revenue above the variable costs of production to pay fixed costs.

A. Aggregate Supply Response for Pork and Beef

The programmed estimates of quantities of pork supplied from Iowa farms at the preselected prices are presented in Table 13. The smallest quantity estimate is 163,893 thousand hundred-weight when the price of pork is $15.91 per hundred-weight. Although this is not the lowest absolute price of pork used in the model, the corn and beef prices corresponding to the price of $15.91 for pork make the lowest programmed pork-corn price ratio (13.6:1) and the highest programmed beef-pork price ratio (1.686:1).

Table 13. Programmed potential of aggregate supply response for liveweight of pork produced in Iowa

Corn price	Beef price	Pork price	Quantity of pork	Pork: corn price ratio	Beef: pork price ratio
($/bu)	($/cwt)	($/cwt)	(1000 cwt)		
.93	23.60	14.88	164,418	16.0:1	1.586:1
		17.11	173,177	18.4:1	1.379:1
		19.34	186,838	20.8:1	1.220:1
1.05	22.79	15.54	165,794	14.8:1	1.467:1
		18.06	178,993	17.2:1	1.262:1
		20.58	188,972	19.6:1	1.107:1
1.17	26.83	15.91	163,893	13.6:1	1.686:1
		18.72	170,818	16.0:1	1.433:1
		21.53	174,424	18.4:1	1.246:1

The largest quantity estimate for pork occurs when the lowest beef-pork price relationship of 1.107:1 is used in the model. The pork-corn price ratio is also relatively high at 19.6:1 and the resulting highest estimate is 188,972 thousand hundred-weight of pork.

The average quantity of pork marketed from Iowa farms in 1966-1968 was 49,420 thousand hundred-weight. Thus, the model estimates range from 3.32 to 3.82 times higher than recent historical production of pork in Iowa. To produce this significantly increased quantity of pork, hog farrowing facilities were purchased at a rate that more than doubled the original resource vector value for farrowing facilities. The capital resources were large enough to allow the purchase of these additional facilities while labor is the limiting resource that prevents still larger supply quantities of pork.

Some of the estimated supply quantities of beef shown in Table 14 are less than recent historical production in Iowa. The estimated quantities of beef range from 26,375 thousand hundred-weight to 48,732 thousand hundred-weight. These estimates are only .53 to .98 of the 1966-68 average of 49,789 thousand hundred-weight of all cattle and calves marketed from Iowa farms which would include some dairy cattle and calves.

The low estimates for quantities of beef show that beef feeding enterprises cannot compete against hogs for the labor resources unless the beef-pork price ratio is higher than about 1.300:1. When the beef-pork price ratio is only about 1.115:1 the estimated quantities of beef produced are grouped around 26,500 thousand hundred-weight regardless of the beef-corn price ratio. Beef-pork price ratios of 1.246:1 up to 1.279:1 result in the estimated quantities of beef increasing from 28,552 thousand hundred-weight to 48,623 thousand hundred-weight even though the beef-corn price ratio is decreasing from 22.9:1 to 20.5:1. The dominating factor is that the pork-corn price relationship is also decreasing, from 18.4:1 to 16.0:1, at the same time the beef-corn price ratio is decreasing.

The four highest beef supply quantity estimates over 48,600 thousand hundred-weight are all quite close together. This is the result of the upward sloping factor supply

Table 14. Programmed potential of aggregate supply response for liveweight of beef produced in Iowa

Corn price	Pork price	Beef price	Quantity of beef[a]	Beef: corn price ratio	Beef: pork price ratio
($/bu)	($/cwt)	($/cwt)	(1000 cwt)		
.93	17.11	19.03	26,527	20.5:1	1.112:1
		21.32	28,552	22.9:1	1.246:1
		23.60	48,669	25.4:1	1.379:1
1.05	18.06	20.21	26,739	19.2:1	1.119:1
		22.79	35,728	21.7:1	1.262:1
		25.35	48,732	24.1:1	1.404:1
1.17	18.72	21.07	26,375	18.0:1	1.127:1
		23.95	48,623	20.5:1	1.279:1
		26.83	48,690	22.9:1	1.433:1

[a]The quantity of beef is the total liveweight marketed for slaughter. No adjustment has been made for the liveweight of feeder cattle purchased and the liveweight of feeder cattle sold was not included.

function used for feeder cattle. The maximum number of feeder cattle available at the first step on the factor supply function were purchased for feeding in each of these four solutions. The small difference in the estimated supply quantities of marketed beef is due to varying amounts of cull beef sold from beef cow herds. Additional intelligence is gained on the supply response for pork and beef by looking at the cross effect of price changes. These results are given in Tables 15 and 16.

Another way to measure the estimates of supply response for pork and beef is to determine what effect a one percent change in the price of pork or price of beef has on the

Table 15. Programmed potential of aggregate cross supply response for liveweight of pork produced in Iowa as the price of beef is varied

Corn price	Pork price	Beef price	Quantity of pork	Beef: corn price ratio	Beef: pork price ratio
($/bu)	($/cwt)	($/cwt)	(1000 cwt)		
.93	17.11	19.03	180,440	20.5:1	1.112:1
		21.32	183,829	22.9:1	1.246:1
		23.60	173,177	25.4:1	1.379:1
1.05	18.06	20.21	183,284	19.2:1	1.119:1
		22.79	178,993	21.7:1	1.262:1
		25.35	170,734	24.1:1	1.404:1
1.17	18.72	21.07	182,105	18.0:1	1.127:1
		23.95	171,980	20.5:1	1.279:1
		26.83	170,818	22.9:1	1.433:1

Table 16. Programmed potential of aggregate cross supply response for liveweight of beef produced in Iowa as the price of pork is varied

Corn price	Beef price	Pork price	Quantity of beef[a]	Pork: corn price ratio	Beef: pork price ratio
($/bu)	($/cwt)	($/cwt)	(1000 cwt)		
.93	23.60	14.88	49,153	16.0:1	1.586:1
		17.11	48,669	18.4:1	1.379:1
		19.34	31,401	20.8:1	1.220:1
1.05	22.79	15.54	49,051	14.8:1	1.467:1
		18.06	35,728	17.2:1	1.262:1
		20.58	30,754	19.6:1	1.107:1
1.17	26.83	15.91	49,186	13.6:1	1.686:1
		18.72	48,690	16.0:1	1.433:1
		21.53	48,507	18.4:1	1.246:1

[a]The quantity of beef is the total liveweight marketed for slaughter. No adjustment has been made for the liveweight of feeder cattle purchased and the liveweight of feeder cattle sold was not included.

aggregate quantities of hogs or beef supplied. In partial equilibrium theory this measure would be called the "elasticity of supply." However, "other conditions" are not held constant in this model so the measure represents a form of aggregate response. It is more appropriate then to call this a "net supply response measure."

The estimated net supply response and cross-net supply response figures are shown in Tables 17 and 18. The estimates are made with the arc elasticity formula:

$$\left(\frac{Q_2 - Q_1}{Q_2 + Q_1}\right) \Big/ \left(\frac{P_2 - P_1}{P_2 + P_1}\right)$$

The net supply response for pork is quite low. A one percent change in the price of pork produces only a .150 up to .620 percent change in the quantity of pork. This inelastic response is due to the restrictive quantities of labor available. All of the labor available for hire is hired in each of the solutions so the production of hogs can be expanded as the price of pork is increased only by taking labor away from other activities.

The net effect of a one percent change in beef price on the supply of pork was also quite low. Five of the cross-net supply response figures shown in Table 18 have the expected negative sign and range from -.060 to -.555. The other

Table 17. Programmed net supply response for pork and beef as the price of pork is varied

Corn price	Beef price	Arc range of pork price	Effect of a one percent change in pork price on quantity supplied of: Pork	Beef
($/bu)	($/cwt)	($/cwt)	(percent)	(percent)
.93	23.60	14.88-17.11	.372	-.007
		17.11-19.34	.620	-3.525
1.05	22.79	15.54-18.06	.510	-2.095
		18.06-20.58	.416	-1.147
1.17	26.83	15.91-18.72	.255	-.062
		18.72-21.53	.150	-.027

Table 18. Programmed net supply response for pork and beef as the price of beef is varied

Corn price	Beef price	Arc range of beef price	Effect of a one percent change in beef price on quantity supplied of: Beef	Pork
($/bu)	($/cwt)	($/cwt)	(percent)	(percent)
.93	17.11	19.03-21.32	.648	.164
		21.32-23.60	5.132	-.555
1.05	18.06	20.21-22.79	2.398	-.197
		22.79-25.35	2.895	-.444
1.17	18.72	21.07-23.95	4.637	-.447
		23.95-26.83	.001	-.060

cross-net supply response figure of .164 is positive because of the way the model is constructed. As the price of beef is increased, the specialized beef farms received more gross revenue from the sale of beef so they could also sell more of other products and still maintain their type-of-farm definition. Thus, they produce and sell more hogs with the aggregate increase in hog production on the beef farms being greater than the decrease in hog production on all other farms.

The aggregate net supply response measures for beef production are more variable but all have the correct sign. The lowest net response of only .001 occurs when the increase in beef price is from $23.95 to $26.83. The maximum number of feeder cattle that can be purchased at the lowest step on the factor supply function are purchased at the $23.95 price for beef. The price change to $26.83 is not a large enough increase to allow the purchase of more feeder cattle at the next step on the factor supply function.

Four of the six net supply response figures show that a one percent change in the price of beef will result in more than a one percent change in the quantity of beef supplied. One-half of the cross-net supply response figures show a greater than one percent change in the quantity of beef for a one percent change in the price of pork.

B. Representative Farm Supply Response for Pork and Beef

Hogs are produced on all of the representative farms used in the model. Tables 19-24 show that only on the large dairy farm in Northeastern Iowa, farm number 25, are hogs not produced at some of the programmed price combinations.

The tables show the supply quantities for the "aggregated

Table 19. Programmed potential of supply response for liveweight of pork produced on aggregated representative farms as the price of pork is varied (corn price = $.93; beef price = $23.60)

Representative farm number	Pork price $14.88	$17.11	$19.34
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
1	3,538.7	3,153.5	2,870.9
2	14,136.1	14,354.9	15,595.6
3	5,259.8	4,817.3	4,377.1
4	6,232.9	5,879.6	5,528.4
5	15,570.3	15,985.9	17,149.2
6	1,070.3	1,062.3	1,288.7
7	9,718.7	10,510.2	11,170.5
8	1,397.9	1,493.1	1,258.7
9	634.1	634.1	5,098.9
10	7,244.0	7,912.6	7,967.4
11	502.7	426.7	435.6
12	5,187.7	5,306.6	5,306.6
13	12,698.0	13,725.9	13,733.0
14	1,432.7	1,837.2	1,651.7
15	24,333.8	24,315.1	28,498.0
16	897.8	796.4	715.6
17	1,265.3	1,103.0	1,342.7
18	10,156.4	10,355.5	10,346.2
19	18,327.7	18,249.6	20,146.2
20	1,081.7	3,485.3	2,954.5
21	13,575.1	17,375.2	19,119.7
22	1,154.1	1,034.5	939.0
23	2,489.8	2,530.5	2,530.5
24	2,929.4	2,986.4	2,986.6
25	292.9	-	-
26	1,248.6	1,637.6	1,508.2
27	2,041.5	2,208.3	2,318.3

Table 20. Programmed potential of supply response for liveweight of pork produced on aggregated representative farms as the price of pork is varied (corn price = $1.05, beef price = $22.79)

Representative farm number	Pork price $15.54	Pork price $18.06	Pork price $20.58
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
1	3,731.6	3,324.1	2,948.7
2	14,234.9	15,287.5	15,595.6
3	5,256.5	4,906.9	4,501.6
4	6,033.8	5,528.4	6,386.8
5	15,890.0	17,149.2	17,694.9
6	1,052.7	1,020.1	1,132.4
7	9,797.1	10,893.7	11,242.0
8	1,019.6	1,530.2	1,390.0
9	634.1	2,997.1	4,887.1
10	7,245.0	7,920.2	7,967.4
11	524.8	513.7	458.8
12	5,094.0	5,211.5	5,211.5
13	13,126.3	13,505.2	13,489.0
14	1,647.8	1,949.0	1,738.2
15	24,718.5	27,107.2	28,840.0
16	953.2	839.0	749.3
17	1,147.3	328.0	1,131.0
18	10,283.9	10,318.2	10,318.9
19	18,384.4	19,720.1	20,327.9
20	926.2	662.3	2,949.7
21	13,936.8	18,350.5	20,056.5
22	1,084.0	966.9	875.0
23	2,457.8	2,457.8	2,457.8
24	2,932.4	2,932.4	2.923.4
25	146.1	-	-
26	1,328.0	1,280.6	1,405.2
27	2,207.6	2,293.4	2,293.4

Table 21. Programmed potential of supply response for liveweight of pork produced on aggregated representative farms as the price of pork is varied (corn price = $1.17, beef price = $26.83)

Representative farm number	Pork price		
	$15.91	$18.72	$21.53
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
1	3,963.6	3,458.1	3,066.9
2	14,240.7	14,953.3	14,953.3
3	3,836.4	4,938.9	4,587.8
4	6,095.4	6,201.8	6,803.3
5	15,845.9	16,297.9	16,012.7
6	1,072.0	1,387.0	988.1
7	10,031.8	10,353.7	11,180.1
8	345.4	1,583.0	1,434.8
9	634.1	1,029.7	634.1
10	7,244.0	7.914.5	7.967.4
11	560.4	546.5	484.7
12	5,011.6	5,127.9	5,127.9
13	12,940.4	13,303.3	13,303.3
14	1,705.4	2,073.4	1,838.6
15	25,555.0	24,968.3	25,181.2
16	1,018.1	888.3	787.8
17	985.5	1,220.8	1,208.2
18	10,281.6	10,283.4	10,282.5
19	18,288.9	18,982.8	18,982.8
20	622.3	1,139.4	1,660.3
21	13,511.4	14,061.8	18,130.3
22	1,032.7	916.7	823.5
23	2,353.2	2,393.6	2,393.6
24	2,806.4	2,876.5	2,876.5
25	306.9	-	-
26	1,358.6	1,599.6	1,469.3
27	2,205.1	2,318.3	2,245.1

Table 22. Programmed potential of supply response for liveweight of pork produced on aggregated representative farms as the price of beef is varied (corn price = $.93, pork price = $17.11)

Representative farm number	Beef price $19.03	$21.32	$23.60
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
1	3,139.0	3,176.6	3,153.5
2	15,016.9	15,015.4	14,354.9
3	4,911.5	4,817.3	4,817.3
4	2,943.5	5,312.4	5,879.6
5	17,149.2	17,149.2	15,985.9
6	950.2	1,016.6	1,062.3
7	11,304.9	11,304.8	10,510.2
8	1,494.0	1,384.8	1,493.1
9	3,332.9	4,006.1	634.1
10	7,913.0	7,913.0	7,912.6
11	442.4	434.5	426.7
12	5,306.6	5,306.6	5,306.6
13	13,668.5	13,697.3	13,725.9
14	1,837.2	1,837.2	1,837.2
15	27,822.7	27,880.3	24,315.1
16	796.4	796.4	796.4
17	543.4	543.4	1,103.0
18	10,357.6	10,358.5	10,355.5
19	19,851.1	19,906.1	18,249.6
20	3,498.2	3,246.4	3,485.3
21	18,350.1	18,630.2	17,375.2
22	1,034.5	1,034.5	1,034.5
23	2,530.5	2,530.5	2,530.5
24	2,986.6	2,986.5	2,986.4
25	306.9	-	-
26	929.4	1,271.4	1,637.6
27	2,322.4	2,272.9	2,208.3

Table 23. Programmed potential of supply response for live-weight of pork produced on aggregated representative farms as the price of beef is varied (corn price = $1.05, pork price = $18.06)

Representative farm number	Beef price $20.21	$22.79	$25.35
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
1	3,284.5	3,324.1	3,284.5
2	15,417.1	15,287.5	14,951.4
3	5,084.2	4,906.9	4,907.3
4	3,029.6	5,528.4	6,130.1
5	17,149.2	17,149.2	16,290.1
6	956.2	1,020.1	1,317.3
7	11,249.8	10,893.7	10,438.6
8	1,527.7	1,530.2	1,530.1
9	4,201.6	2,997.1	634.1
10	7,914.5	7,920.2	7,914.5
11	513.7	513.7	513.7
12	5,211.5	5,211.5	5,211.5
13	13,505.2	13,505.2	13,505.2
14	1,949.0	1,949.0	1,949.0
15	28,555.6	27,107.2	25,286.5
16	839.0	839.0	839.0
17	267.9	328.0	833.6
18	10,319.6	10,318.2	10,317.9
19	20,357.1	19,720.1	18,997.6
20	3,553.6	662.3	924.2
21	18,795.4	18,350.5	14,680.9
22	966.9	966.9	966.9
23	2,457.8	2,457.8	2,457.8
24	2,932.3	2,932.4	2,932.3
25	-	-	-
26	922.6	1,280.6	1,618.0
27	2,322.3	2,293.4	2,301.8

Table 24. Programmed potential of supply response for liveweight of pork produced on aggregated representative farms as the price of beef is varied (corn price = $1.17, pork price = $18.72)

Representative farm number	Beef price $21.07	$23.95	$26.83
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
1	3,458.1	3,458.1	3,458.1
2	15,595.6	14,971.1	14,953.3
3	5,342.2	4,938.9	4,938.9
4	2,998.9	5,908.9	6,201.8
5	17,149.2	16,527.8	16,297.9
6	957.6	1,241.8	1,387.0
7	11,200.9	10,389.2	10,353.7
8	1,583.0	1,583.0	1,583.0
9	4,040.7	2,207.2	1,029.7
10	7,965.3	7,914.5	7,914.5
11	546.5	546.5	546.5
12	5,127.9	5,127.9	5,127.9
13	13,303.3	13,303.3	13,303.3
14	2,073.4	2,073.4	2,073.4
15	27,028.1	24,620.2	24,968.3
16	888.3	888.3	888.3
17	270.7	839.7	1,220.8
18	10,256.6	10,283.4	10,283.4
19	20,325.4	19,267.6	18,982.8
20	3,656.6	662.3	1,139.4
21	18,870.4	15,220.2	14,061.8
22	916.0	916.7	916.7
23	2,393.6	2,393.6	2,393.6
24	2,876.5	2,876.5	2,876.5
25	-	-	-
26	957.9	1,501.7	1,599.6
27	2,322.3	2,318.3	2,318.3

representative farms" as they appear in the model. The data in this form provides additional insights into the source of the aggregate supply response for the state. In general, significant quantities of hogs are produced in each area of the state and on both small and large farms. The type-of-farm constraint (gross sales accounting equation) causes backward bending supply functions on several farms. If the type-of-farm constraints on a cash grain, beef or dairy farm is restrictive, an increase in the price of pork has to result in less hogs produced on that farm.

The supply response for hogs on the specialized hog farms, numbers 12, 18 and 23, is quite inelastic. The quantities of pork produced on these farms often does not change or changes very little from one pork price to the next or from one beef price to the next.

Tables 25-30 show the aggregate representative farm supply quantities for beef at the different prices for beef or for hogs. At many of the programmed price combinations a majority of the farms do not feed beef. When the corn price is $1.05, pork price is $20.58 and the beef price is $22.79, only the four specialized beef farms produce beef. Only when the pork-corn price relationship is low and the beef-pork price relationship is high do a majority of the farms feed some beef.

The type-of-farm constraint again causes a few beef

Table 25. Programmed potential of supply response for liveweight of beef produced on aggregated representative farms as the price of beef is varied (corn price = \$.93, pork price = \$17.11)

Representative farm number	Beef price \$19.03	\$21.32	\$23.60
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
1	-	-	-
2	-	-	963.3
3	-	-	-
4	12,531.9	14,344.6	13,577.0
5	-	-	1,881.3
6	1,987.4	1,988.6	2,742.8
7	-	-	750.5
8	-	-	-
9	9,664.9	9,560.3	15,297.9
10	-	-	-
11	10.4	10.4	10.5
12	-	-	-
13	12.4	6.9	1.4
14	-	-	-
15	284.7	267.9	5,493.1
16	-	-	-
17	-	-	-
18	-	-	-
19	-	-	2,392.1
20	-	-	-
21	91.5	.6	2,629.6
22	-	-	-
23	-	-	-
24	-	-	-
25	-	-	-
26	1,944.1	2,372.2	2,760.6
27	-	-	169.6

Table 26. Programmed potential of supply response for liveweight of beef produced on aggregated representative farms as the price of beef is varied (corn price = $1.05, pork price = $18.06)

Representative farm number	Beef price $20.21	$22.79	$25.35
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
1	-	-	-
2	-	495.1	963.3
3	-	-	-
4	12,301.0	14,049.4	13,306.3
5	-	-	1,322.1
6	1,987.3	1,965.8	2,260.0
7	-	-	713.3
8	-	-	-
9	10,453.1	12,497.7	15,445.4
10	-	-	-
11	-	-	-
12	-	-	-
13	-	-	-
14	-	-	-
15	80.0	387.0	3,637.8
16	-	-	-
17	-	-	-
18	-	-	-
19	-	998.6	1,986.0
20	-	2,477.0	2,060.4
21	-	497.4	4,356.7
22	-	-	-
23	-	-	-
24	-	-	-
25	-	-	-
26	1,917.4	2,359.9	2,680.8
27	-	-	-

Table 27. Programmed potential of supply response for liveweight of beef produced on aggregated representative farms as the price of beef is varied (corn price = $1.17, pork price = $18.72)

Representative farm number	Beef price $21.07	$23.95	$26.83
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
1	-	-	-
2	-	963.3	963.3
3	-	-	-
4	12,210.1	13,681.6	13,005.9
5	-	1,322.1	1,322.1
6	1,978.6	2,338.8	2,322.9
7	-	883.2	776.2
8	-	-	-
9	9,824.8	13,534.4	14,809.4
10	-	-	-
11	-	-	-
12	-	-	-
13	-	-	-
14	-	-	-
15	382.1	4,955.9	4,030.8
16	-	-	-
17	-	-	-
18	-	-	-
19	-	1,609.8	1,968.5
20	-	2,572.2	1,975.5
21	-	4,032.4	4,920.8
22	-	-	-
23	-	-	-
24	-	-	-
25	-	-	-
26	1,979.3	2,729.3	2,594.8
27	-	-	-

Table 28. Programmed potential of supply response for live-weight of beef produced on aggregated representative farms as the price of pork is varied (corn price = $.93, beef price = $23.60)

Representative farm number	Pork price $14.88	Pork price $17.11	Pork price $19.34
	(1,000 cwt)	(1,000 cwt)	)1,000 cwt)
1	-	-	-
2	963.3	963.3	-
3	81.2	-	-
4	12,924.6	13,577.0	13,960.9
5	1,861.0	1,881.3	-
6	1,655.3	2,742.8	2,585.4
7	969.2	750.5	-
8	111.9	-	-
9	13,306.4	15,297.9	10,626.7
10	95.7	-	-
11	10.4	10.5	-
12	31.4	-	-
13	898.0	1.4	-
14	101.8	-	-
15	4,231.2	5,493.1	97.8
16	-	-	-
17	-	-	-
18	50.7	-	-
19	2,392.1	2,392.1	292.7
20	1,975.5	-	-
21	5,286.4	2,629.6	963.6
22	-	-	-
23	9.6	-	-
24	-	-	-
25	-	-	-
26	1,830.5	2,760.6	2,873.7
27	366.9	169.6	-

Table 29. Programmed potential of supply reponse for liveweight of beef produced on aggregated representative farms as the price of pork is varied (corn price = $1.05, beef price = $22.79)

Representative farm number	Pork price $15.54	$18.06	$20.58
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
1	-	-	-
2	963.3	495.1	-
3	9.7	-	-
4	13,424.0	14,049.4	14,514.2
5	1,327.3	-	-
6	1,755.2	1,965.8	2,464.0
7	1,103.9	-	-
8	555.0	-	-
9	13,703.7	12,497.7	11,184.7
10	95.2	-	-
11	10.4	-	-
12	31.4	-	-
13	96.0	-	-
14	101.8	-	-
15	4,185.4	387.0	-
16	-	-	-
17	-	-	-
18	42.2	-	-
19	2,360.5	998.6	-
20	2,330.0	2,477.0	-
21	4,680.1	497.4	-
22	-	-	-
23	-	-	-
24	-	-	-
25	-	-	-
26	2,105.9	2,359.9	2,950.9
27	169.7	-	-

Table 30. Programmed potential of supply response for live-weight of beef produced on aggregated representative farms as the price of pork is varied (corn price = $1.17, beef price = $26.83)

Representative farm number	Pork price $15.91	$18.72	$21.53
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
1	-	-	-
2	963.3	963.3	963.3
3	1,303.9	-	-
4	12,722.7	13,005.9	13,591.7
5	1,322.1	1,322.1	2,221.0
6	1,652.7	2,322.9	2,860.3
7	1,093.7	776.2	26.1
8	1,008.3	-	-
9	14,380.2	14,809.4	15,509.0
10	95.7	-	-
11	10.4	-	-
12	31.4	-	-
13	96.0	-	-
14	101.8	-	-
15	2,669.4	4,030.8	5,051.1
16	-	-	-
17	-	-	-
18	-	-	-
19	2,392.1	1,968.5	1,968.5
20	2,367.0	1,975.5	1,395.2
21	4,920.6	4,920.8	2,064.3
22	-	-	-
23	9.6	-	-
24	2.0	-	-
25	-	-	-
26	1,873.1	2,594.8	2,741.3
27	170.3	-	115.5

production shifts that form a backward bending supply function but this is not as prevalent as in the pork supply response functions. The specialized beef farms, numbers 4, 6, 9 and 26, account for a majority of the beef production at all price combinations and generally have quite significant supply quantity responses to a change in the price of beef or the price of pork.

C. Quantities of Resources Used and Adjustment Implications

Economic implications for areas, sizes and types of farms in Iowa can be drawn from the study by analyzing the resource use information from the model solutions. Any differences between the mix and quantities of resources used in the model and currently in use on Iowa farms suggests further resource adjustment problems. It is because of the implied changes in resource use that supply response studies are often called "adjustment studies", for example, the regional adjustment studies.

Analyses of the resource use information may suggest adjustments in the total quantities of resources used or only in the mix of resources used. The strength of any resource adjustment implication is dependent on the strength of the empirical estimates of supply response derived from the model.

1. Cropland and non-cropland pasture

The land resources on each farm were divided into cropland and non-cropland pasture. An examination of the marginal value of an additional acre of cropland or of non-cropland pasture is a means to analyze the land resources.

Tables 31-33 show the marginal value of one additional acre of cropland for each solution and for each representative farm. Cropland was a restrictive resource in all cases except for the dairy farm number 25 when the price of corn was $1.05 and pork and beef were priced at $20.58 and $22.79 respectively.

The marginal value of one additional acre of non-cropland pasture is shown in Tables 34-36. This resource is in surplus supply in many of the model solutions. The beef farms, numbers 4, 6, 9 and 26, and the dairy farms, numbers 17, 22 and 25, generally have a positive shadow price value for this resource. Many other farms had a positive shadow price only when the pork-corn price ratio was low and the beef-pork price ratio was high.

2. Labor resources

The labor resource information used in the model divided the labor used on Iowa farms into types of labor and into calendar periods. To keep the analyses of labor use information from being excessively burdensome, only a portion of the information is presented here.

Table 31. Marginal value of one additional acre of cropland when the price of corn is $.93

Pork price	14.88		17.11		19.34
Beef price	23.60	19.03	21.32	23.60	23.60
Representative farm number					
1	32.92	35.05	35.05	35.05	36.35
2	35.20	33.77	36.85	36.66	39.00
3	28.49	28.45	29.84	31.31	34.03
4	35.40	23.35	30.46	37.41	32.66
5	32.05	28.84	32.49	31.95	32.08
6	22.71	23.94	26.70	27.38	21.82
7	22.83	23.87	22.67	21.99	23.46
8	10.69	14.96	11.09	10.43	10.06
9	23.87	10.22	15.66	26.46	21.32
10	9.46	12.15	8.34	7.77	14.26
11	27.72	46.45	44.51	40.02	23.90
12	29.08	33.38	33.38	33.38	37.38
13	22.85	24.85	23.69	25.12	26.00
14	21.49	22.85	22.84	23.12	23.78
15	13.50	11.65	10.55	9.55	17.16
16	30.36	32.33	32.33	32.33	33.52
17	38.24	27.24	27.22	27.23	27.75
18	34.30	38.67	37.22	37.52	40.09
19	28.71	30.72	31.62	33.36	34.41
20	22.78	26.89	25.25	22.28	22.74
21	25.80	30.36	31.16	23.38	30.81
22	31.00	22.95	22.95	25.75	19.72
23	40.90	47.12	47.12	47.60	53.50
24	30.29	32.90	32.90	33.44	37.90
25	22.40	23.82	11.90	15.72	1.11
26	26.40	26.16	20.60	25.44	21.31
27	29.94	16.60	25.14	29.64	19.04

Table 32. Marginal value of one additional acre of cropland when the price of corn is $1.05

Pork price	15.54		18.06		20.58
Beef price	22.79	20.21	22.79	25.35	22.79
Representative farm number					
1	34.68	40.14	40.14	39.56	41.70
2	36.42	36.71	38.96	39.81	38.82
3	29.55	32.37	28.59	28.41	39.77
4	33.70	29.12	35.41	36.82	29.87
5	33.55	32.59	33.83	35.88	30.02
6	25.16	30.25	28.21	27.33	21.20
7	24.26	28.32	25.89	26.71	27.20
8	12.45	14.68	11.70	10.88	9.37
9	24.36	15.15	20.86	26.37	24.74
10	9.06	13.56	12.95	8.26	12.34
11	22.65	26.74	26.74	26.30	27.90
12	31.84	38.84	38.84	38.52	43.92
13	24.00	31.03	30.11	31.25	31.32
14	22.65	25.99	25.75	25.70	26.59
15	13.27	14.76	15.26	13.38	18.39
16	31.99	37.02	37.02	36.49	38.45
17	36.83	20.05	32.52	29.55	28.16
18	35.90	43.23	41.11	41.55	45.21
19	29.91	32.40	33.45	33.50	36.12
20	22.41	34.03	26.62	27.87	24.70
21	26.45	31.64	30.53	26.84	27.86
22	29.60	35.03	35.03	35.71	30.16
23	44.28	53.69	53.69	53.78	61.54
24	32.92	38.23	40.54	38.32	47.61
25	16.59	14.78	1.05	7.83	-
26	24.43	21.77	23.41	30.31	17.67
27	28.96	19.35	24.03	25.31	28.64

Table 33. Marginal value of one additional acre of cropland when the price of corn is $1.17

Pork price	15.91		18.72		21.53
Beef price	26.83	21.07	23.95	26.83	26.83
Representative farm number					
1	37.27	43.32	41.80	41.50	44.80
2	37.24	38.23	40.80	40.68	43.69
3	27.80	35.93	30.61	30.39	41.99
4	33.68	30.37	34.96	35.14	34.93
5	35.50	33.61	36.74	36.68	28.51
6	24.47	32.63	26.14	29.05	35.34
7	26.57	30.92	29.04	28.47	32.49
8	12.78	13.90	11.77	9.88	7.89
9	29.68	15.33	26.85	28.07	34.88
10	11.52	15.41	13.87	7.65	10.26
11	24.58	29.11	27.97	27.75	30.22
12	34.59	42.73	41.96	41.80	48.77
13	26.15	31.71	32.35	33.39	41.46
14	24.11	27.69	26.91	26.99	30.04
15	15.76	17.74	14.83	13.37	7.90
16	34.37	39.95	38.55	38.27	41.31
17	35.12	21.67	26.39	26.05	30.40
18	38.56	45.54	44.03	44.17	51.42
19	30.63	33.38	35.47	34.82	38.50
20	28.24	35.63	30.03	30.10	34.91
21	28.88	32.32	28.33	27.23	24.53
22	34.22	37.65	34.41	32.99	29.26
23	47.49	58.36	57.90	57.73	67.36
24	43.35	53.86	53.39	53.22	62.41
25	17.90	4.99	1.33	3.37	0.95
26	31.10	24.81	26.58	29.97	29.37
27	27.79	20.11	21.43	20.84	18.65

Table 34. Marginal value of one additional acre of non-cropland pasture when the price of corn is $.93

Pork price	14.88		17.11		19.34
Beef price	23.60	19.03	21.32	23.60	23.60
Representative farm number					
1	-	-	-	-	-
2	8.52	-	-	5.46	-
3	-	-	-	-	-
4	13.65	13.02	14.57	16.67	17.36
5	10.79	-	-	8.53	-
6	13.93	14.58	15.94	17.22	13.46
7	.87	-	-	-	-
8	1.22	-	-	-	-
9	14.84	8.46	10.40	16.48	13.49
10	1.31	-	-	-	-
11	4.48	2.31	4.00	4.37	-
12	2.45	-	-	-	-
13	1.53	-	-	-	-
14	1.83	-	-	-	-
15	1.97	-	-	-	-
16	-	-	-	-	-
17	22.48	16.23	16.22	16.26	15.63
18	-	-	-	-	-
19	.70	-	-	10.16	-
20	4.85	-	-	-	-
21	2.15	-	-	-	-
22	16.37	12.61	12.61	14.00	11.19
23	1.07	-	-	-	-
24	-	-	-	-	-
25	12.15	13.02	7.49	9.23	2.55
26	12.72	12.61	10.44	12.60	11.15
27	-	-	-	-	-

Table 35. Marginal value of one additional acre of noncropland pasture when the price of corn is $1.05

Pork price	15.54		18.06		20.58
Beef price	22.79	20.21	22.79	25.35	22.79
Representative farm number					
1	-	-	-	-	-
2	8.12	-	-	3.14	-
3	-	-	-	-	-
4	13.94	13.83	16.06	16.93	17.46
5	10.38	-	-	5.10	-
6	15.42	17.30	16.51	16.17	12.84
7	0.75	-	-	-	-
8	-	-	-	-	-
9	14.85	10.12	12.69	15.78	14.88
10	0.06	-	-	-	-
11	0.78	-	-	-	-
12	1.53	-	-	-	-
13	0.07	-	-	-	-
14	1.02	-	-	-	-
15	0.23	-	0.32	-	-
16	-	-	-	-	-
17	21.88	13.57	20.55	18.84	16.92
18	-	-	-	-	-
19	-	-	-	-	-
20	5.87	-	2.02	3.60	-
21	0.20	-	-	-	-
22	15.75	18.65	18.65	18.98	16.44
23	-	-	-	-	-
24	-	-	-	-	-
25	9.35	8.37	2.52	5.73	-
26	12.10	10.84	11.81	14.54	9.53
27	-	-	-	-	-

Table 36. Marginal value of one additional acre of non-cropland pasture when the price of corn is $1.17

Pork price	15.91		18.72		21.53
Beef price	26.83	21.07	23.95	26.83	26.83
Representative farm number					
1	-	-	-	-	-
2	8.36	-	1.11	3.41	7.38
3	5.02	-	-	-	-
4	12.30	15.23	19.15	17.57	20.31
5	10.00	-	2.46	5.16	3.47
6	14.42	18.64	15.15	17.24	21.30
7	2.98	-	-	-	-
8	0.96	-	-	-	-
9	17.63	10.19	15.82	16.71	20.76
10	1.36	-	-	-	-
11	0.51	-	-	-	-
12	2.46	-	-	-	-
13	1.43	-	-	-	-
14	0.73	-	-	-	-
15	1.49	-	-	-	-
16	-	-	-	-	-
17	21.79	14.51	17.05	16.69	17.56
18	-	-	-	-	-
19	0.55	-	-	-	-
20	9.21	-	4.69	3.17	-
21	7.44	-	-	-	-
22	18.03	19.99	18.40	17.69	16.06
23	0.78	-	-	-	-
24	-	-	-	-	-
25	10.09	4.10	2.63	3.58	2.48
26	14.68	12.06	13.22	14.57	14.78
27	-	-	-	-	-

Tables 37-41 present figures showing the excess operator and family labor found on farms for each of the five model solutions when the price of corn was $1.05. The tabled figures are the average hours of excess operator and family labor found on each representative farm. The excess hours of labor shown are excess in the sense that they are not needed for the production activities included in the model solution and are not needed for the "overhead" activities that needed to be performed in each calendar period. Other activities on Iowa farms such as poultry, sheep and horses and "overhead" activities that could be performed at any time during the year would reduce the hours of excess labor.

Even though the cash grain farm generally have fewer hours of operator and family labor available than do other farms of the same size, the major quantities of excess labor are also found on these farms. These are farms numbered 1, 3, 8, 11, 14, 16 and 20. The hours of excess operator and family labor on other farms would be higher if the estimates of supply response for pork were closer to historical quantities supplied from Iowa farms.

The labor available for hire can be analyzed in two ways. Tables 42-46 show the average number of hours hired on each representative farm for the five model solutions when the price of corn is $1.05. These tables show the hours of full-time labor hired on each farm and the hours of seasonal

Table 37. Average hours of excess operator and family labor by periods for each representative farm (corn = $1.05, pork = $15.54, beef = $22.79)

Representative farm number	Calendar period				
	Dec.-Mar.	Apr.-May	June-July	Aug.-Sept.	Oct.-Nov.
1	88.6	114.0	159.1	153.7	13.7
2	86.1	123.1	38.5	-	-
3	57.6	-	-	60.3	-
4	-	-	-	-	-
5	-	-	-	-	-
6	116.3	58.8	-	1.1	-
7	-	-	-	-	-
8	205.3	19.4	-	45.9	-
9	55.9	-	-	-	-
10	-	-	-	-	-
11	265.7	245.4	184.6	220.8	111.7
12	150.5	108.3	17.7	15.9	43.7
13	-	76.2	33.5	-	-
14	168.6	150.2	115.8	174.0	-
15	-	-	-	-	-
16	163.5	139.6	190.7	134.6	99.4
17	-	90.2	108.3	-	44.7
18	117.9	21.8	12.9	-	-
19	40.0	-	-	-	-
20	405.2	33.5	-	4.2	-
21	181.5	-	-	-	-
22	-	58.6	-	3.1	66.3
23	126.5	70.6	76.8	42.2	44.1
24	-	169.4	51.2	-	82.3
25	-	-	-	-	-
26	51.5	17.9	-	-	58.7
27	-	-	-	-	-

Table 38. Average hours of excess operator and family labor by periods for each representative farm (corn = $1.05, pork = $18.06, beef = $20.21)

Representative farm number	Calendar period				
	Dec.-Mar.	Apr.-May	June-July	Aug.-Sept.	Oct.-Nov.
1	109.1	125.8	169.0	165.2	23.9
2	-	103.9	69.6	-	-
3	22.9	16.7	-	35.0	-
4	241.4	-	-	-	-
5	-	-	-	-	-
6	148.2	51.2	-	0.5	-
7	-	-	-	-	-
8	87.0	54.5	-	34.5	-
9	-	-	-	-	-
10	-	-	-	-	-
11	289.2	255.9	196.1	232.0	114.5
12	180.7	119.7	44.6	37.1	50.6
13	19.0	83.4	52.6	-	-
14	335.9	237.5	113.8	199.6	-
15	-	-	-	-	-
16	180.6	149.5	199.0	144.1	107.9
17	-	103.9	216.0	163.0	48.6
18	117.6	24.4	12.1	-	-
19	-	29.8	76.1	-	-
20	127.6	48.8	-	-	-
21	-	-	-	-	-
22	-	59.7	-	-	68.5
23	126.5	70.6	76.8	42.2	44.1
24	-	168.4	51.9	-	81.7
25	-	-	-	-	-
26	225.0	93.9	-	19.5	9.0
27	-	-	-	-	-

Table 39. Average hours of excess operator and family labor by periods for each representative farm (corn = $1.05, pork = $18.06, beef = $22.79)

Representative farm number	Calendar period				
	Dec.-Mar.	Apr.-May	June-July	Aug.-Sept.	Oct.-Nov.
1	109.1	123.0	146.6	147.0	23.2
2	-	98.3	66.3	-	-
3	40.7	35.8	-	44.4	-
4	-	-	-	-	-
5	-	-	-	-	-
6	112.6	54.2	-	-	-
7	-	-	-	-	-
8	86.8	54.9	-	30.2	-
9	-	-	-	-	-
10	-	-	-	-	-
11	289.2	255.9	196.1	232.0	114.5
12	180.7	119.6	44.6	37.1	50.6
13	19.0	83.4	52.6	-	-
14	335.9	237.5	113.8	199.6	-
15	-	-	-	-	-
16	180.6	149.5	199.0	144.1	107.9
17	-	102.9	208.7	148.6	48.6
18	118.3	24.9	11.5	-	-
19	-	2.2	71.7	-	-
20	426.7	40.1	-	13.2	-
21	-	-	-	-	-
22	-	59.7	-	-	68.5
23	126.5	70.6	76.8	42.2	44.1
24	-	169.4	51.2	-	82.3
25	-	-	-	-	-
26	39.7	15.1	-	-	101.0
27	-	-	-	-	-

Table 40. Average hours of excess operator and family labor by periods for each representative farm (corn = $1.05, pork = $18.06, beef = $25.35)

Representative farm number	Calendar period: Dec.-Mar.	Apr. May	June-July	Aug.-Sept.	Oct.-Nov.
1	109.1	125.8	169.0	165.2	23.9
2	-	83.8	79.7	-	-
3	40.7	35.8	-	44.3	-
4	-	-	-	-	-
5	-	-	-	-	-
6	37.7	-	-	-	-
7	-	-	-	-	-
8	86.8	54.9	-	30.1	-
9	77.1	-	-	-	-
10	-	-	-	-	-
11	289.2	255.9	196.1	232.0	114.5
12	180.7	119.7	44.6	37.1	50.6
13	19.0	83.4	52.6	-	-
14	335.9	237.5	113.8	199.6	-
15	-	-	-	-	-
16	180.6	149.5	199.0	144.1	107.9
17	-	94.9	147.9	27.5	49.1
18	118.5	25.0	11.3	-	-
19	17.0	-	64.5	-	-
20	399.6	50.6	-	11.1	-
21	99.2	-	-	-	-
22	-	59.7	-	-	68.5
23	126.5	70.6	76.8	42.2	44.1
24	-	168.4	51.9	-	81.7
25	-	-	-	-	-
26	-	-	-	-	17.9
27	-	-	-	-	-

Table 41. Average hours of excess operator and family labor by periods for each respective farm (corn = \$1.05, pork = \$20.58, beef = \$22.79)

Representative farm number	Calendar period				
	Dec.-Mar.	Apr.-May	June-July	Aug.-Sept.	Oct.-Nov.
1	125.2	133.9	167.0	166.2	31.7
2	-	113.0	53.0	-	-
3	67.0	38.7	-	58.1	-
4	-	-	-	-	-
5	-	-	-	-	-
6	85.8	11.4	-	-	-
7	-	-	-	-	-
8	113.6	63.7	-	41.2	-
9	-	-	-	-	-
10	-	-	-	-	-
11	299.1	261.6	200.8	237.6	119.5
12	180.7	119.7	44.6	37.1	50.6
13	8.0	82.9	70.0	-	-
14	351.9	246.0	129.8	214.0	-
15	-	-	-	-	-
16	194.0	157.2	205.5	151.7	114.6
17	-	102.8	67.7	-	75.9
18	118.0	24.6	11.8	-	-
19	-	28.6	72.1	-	-
20	197.6	89.1	-	18.0	-
21	-	-	-	-	-
22	-	59.6	-	-	70.8
23	126.5	70.6	76.8	42.3	44.1
24	-	168.4	51.6	-	82.9
25	-	-	-	-	88.1
26	-	-	-	-	-
27	-	-	-	-	-

Table 42. Average hours of labor hired on each representative farm (corn = $1.05, pork = $15.54, beef = $22.79)

Representative farm number	Full-time labor[a]	Seasonal labor Apr.-May	June-July	Aug.-Sept.	Oct.-Nov.	Total
1	-	-	-	-	-	-
2	-	-	-	14	27	41
3	-	-	25	-	-	25
4	860	-	11	-	146	1,017
5	896	-	-	8	26	930
6	-	-	-	-	-	-
7	450	-	-	6	-	456
8	301	-	18	-	-	319
9	1,830	-	-	-	60	1,890
10	875	-	1	-	-	876
11	-	-	-	-	-	-
12	-	-	-	-	-	-
13	-	-	-	15	10	25
14	-	-	-	-	30	30
15	997	-	34	8	25	1,064
16	-	-	-	-	-	-
17	-	-	-	-	-	-
18	125	-	-	-	46	171
19	176	-	-	-	-	176
20	119	-	21	-	-	140
21	625	-	-	6	-	631
22	-	-	-	-	-	-
23	-	-	-	-	-	-
24	21	-	-	1	-	1
25	1,254	-	-	-	-	2,154
26	44	-	61	32	126	263
27	1,278	-	-	-	89	1,367

[a]Each hour of full-time hired labor was divided into .2586 hr. for Dec.-Mar., .1863 hr. for April-May, .1965 hr. for June-July, .1815 hr. for Aug.-Sept., and .1771 hr. for Oct.-Nov.

Table 43. Average hours of labor hired on each representative farm (corn = $1.05, pork = $18.06, beef = $20.21)

Representative farm number	Full-time labor[a]	Seasonal labor Apr.-May	June-July	Aug.-Sept.	Oct.-Nov.	Total
1	-	-	-	-	-	-
2	-	-	-	-	43	43
3	68	-	-	-	43	111
4	44	-	-	-	51	95
5	914	-	-	-	38	952
6	-	-	-	-	-	-
7	548	-	-	-	29	977
8	286	-	-	-	3	289
9	2,571	-	-	-	-	2,571
10	811	-	-	-	-	811
11	-	-	-	-	-	-
12	-	-	-	-	-	-
13	-	-	-	-	7	7
14	-	-	-	-	11	11
15	1,016	-	-	-	35	1,051
16	-	-	-	-	-	-
17	-	-	-	-	-	-
18	122	-	-	-	47	169
19	152	-	-	-	-	152
20	437	-	-	-	-	437
21	711	-	-	-	-	711
22	-	-	-	-	-	-
23	-	-	-	-	-	-
24	-	-	-	-	-	-
25	2,121	-	-	-	-	2,121
26	-	-	-	-	-	-
27	1,358	-	-	-	19	1,377

[a]Each hour of full-time hired labor was divided into .2586 hr. for Dec.-Mar., .1863 hr. for April-May, .1965 hr. for June-July, .1815 hr. for Aug.-Sept., and .1771 hr. for Oct.-Nov.

Table 44. Average hours of labor hired on each representative farm (corn = $1.05, pork = $18.06, beef = $22.79)

Representative farm number	Full-time labor[a]	Seasonal labor Apr.-May	June-July	Aug.-Sept.	Oct.-Nov.	Total
1	-	-	-	-	-	-
2	-	-	-	4	33	37
3	-	-	12	-	-	12
4	705	-	-	-	126	831
5	914	-	-	-	38	952
6	-	-	-	-	-	-
7	520	-	-	1	10	531
8	286	-	7	-	-	293
9	2,158	-	-	-	40	2,198
10	806	-	-	-	-	806
11	-	-	-	-	-	-
12	-	-	-	-	-	-
13	-	-	-	-	7	7
14	-	-	-	-	11	11
15	1,047	-	12	5	35	1,099
16	-	-	-	-	-	-
17	-	-	-	-	-	-
18	124	-	-	-	47	171
19	159	-	-	-	-	159
20	113	-	7	-	-	120
21	748	-	-	1	-	749
22	-	-	-	-	-	-
23	-	-	-	-	-	-
24	-	-	-	1	-	1
25	1,571	-	-	-	-	1,571
26	-	-	22	6	174	202
27	1,381	-	-	-	29	1,410

[a]Each hour of full-time hired labor was divided into .2586 hr. for Dec.-Mar., .1863 hr. for April-May, .1965 hr. for June-July, .1815 hr. for Aug.-Sept., and .1771 hr. for Oct.-Nov.

Table 45. Average hours of labor hired on each representative farm (corn = $1.05, pork = $18.06, beef = $25.35)

Representative farm number	Full-time labor[a]	Seasonal labor Apr.-May	June-July	Aug.-Sept.	Oct.-Nov.	Total
1	-	-	-	-	-	-
2	-	-	-	1	29	30
3	-	-	12	-	-	12
4	888	-	-	-	151	1,039
5	898	-	-	10	22	930
6	145	-	-	4	-	149
7	532	-	-	1	-	533
8	286	-	7	-	-	293
9	1,972	-	-	-	61	2,033
10	811	-	-	-	-	811
11	-	-	-	-	-	-
12	-	-	-	-	-	-
13	-	-	-	-	7	7
14	-	-	-	-	11	11
15	980	-	12	9	35	1,036
16	-	-	-	-	-	-
17	-	-	-	-	-	-
18	124	-	-	-	47	171
19	152	-	-	-	-	152
20	144	-	-	7	-	151
21	600	-	-	3	-	603
22	-	-	-	-	-	-
23	-	-	-	-	-	-
24	-	-	-	-	-	-
25	1,943	-	-	-	-	1,943
26	511	-	5	14	162	692
27	1,335	-	23	-	44	1,402

[a]Each hour of full-time hired labor was divided into .2586 hr. for Dec.-Mar., .1863 hr. for April-May, .1965 hr. for June-July, .1815 hr. for Aug.-Sept., and .1771 hr. for Oct.-Nov.

Table 46. Average hours of labor hired on each representative farm (corn = $1.05, pork = $20.58, beef = $22.79)

Representative farm number	Full-time labor[a]	Seasonal labor				Total
		Apr.-May	June-July	Aug.-Sept.	Oct.-Nov.	
1	-	-	-	-	-	-
2	-	-	-	8	36	44
3	-	-	-	-	23	23
4	799	-	-	-	132	931
5	987	-	-	-	2	989
6	-	-	-	3	-	3
7	548	-	-	-	29	577
8	310	-	-	-	-	310
9	2,877	-	-	3	-	2,880
10	764	-	-	-	2	766
11	-	-	-	-	-	-
12	-	-	-	-	-	-
13	-	-	-	-	4	4
14	-	-	-	-	-	-
15	979	-	-	9	42	1,030
16	-	-	-	-	-	-
17	-	-	-	-	-	-
18	123	-	-	-	47	170
19	152	-	-	2	-	154
20	1	-	-	-	-	1
21	725	-	-	-	-	725
22	-	-	-	-	-	-
23	-	-	-	-	-	-
24	-	-	-	1	-	1
25	240	-	-	-	67	307
26	501	-	-	11	68	580
27	1,381	-	-	-	29	1,410

[a]Each hour of full-time hired labor was divided into .2586 hr. for Dec.-Mar., .1863 hr. for April-May, .1965 hr. for June-July, .1815 hr. for Aug.-Sept., and .1771 hr. for Oct.-Nov.

labor hired in each period. Full-time labor may be hired even though there is excess operator and family labor on a farm in some periods because the labor is needed in other critical periods and is not available as seasonal labor.

The majority of the full-time labor is hired for use on the large farms in the state. The beef farms, numbers 4, 6, 9 and 26, hire more labor as the beef-pork price ratio increases. The dairy farm hiring labor, number 25, cannot compete for labor at higher prices of pork and beef as well as it could at the lower prices for these products.

The other way to analyze the hired labor resource is to look at the shadow prices for these constraints. This information is shown in Tables 47-51. The first table shows that the marginal value of one additional hour of full-time hired labor increased as the pork-corn and beef-corn price ratios increased. The shadow price values range from \$2.116 to \$4.650 with only one value over \$4.00.

Tables 48-51 show the marginal value of one additional hour of total labor for hire for each calendar period. This is a shadow price on the total hired labor for a period rather than just the seasonal labor for the period because of the way the model was constructed. The required division of total hired labor to full-time and to seasonal hired was that at least 74.66 percent of all labor hired be in the form of full-time labor. Because the labor need for the

Table 47. Marginal value of one additional hour of full-time hired labor on Iowa farms

Corn price	Pork price	Beef price	Value
($/bu)	($/cwt)	($/cwt)	
.93	14.88	23.60	2.116
	17.11	19.03	2.302
		21.32	3.062
		23.60	2.900
	19.34	23.60	3.887
1.05	15.54	22.79	2.572
	18.06	20.21	2.921
		22.79	3.936
		25.35	3.529
	20.58	22.79	4.650
1.17	15.91	26.83	2.576
	18.72	21.07	3.644
		23.95	3.855
		26.83	3.702
	21.53	26.83	3.959

Table 48. Marginal value of one additional hour of April-May hired labor by areas

Corn price	Pork price	Beef price	Area 1	2	3	4	5
($/bu)	($/cwt)	($/cwt)					
.93	14.88	23.60	1.613	3.737	2.295	3.026	.569
	17.11	19.03	2.272	7.193	1.640	-	-
		21.32	.952	10.727	2.569	-	.190
		23.60	2.746	4.552	3.411	4.296	.562
	19.34	23.60	2.393	2.416	.987	1.304	1.235
1.05	15.54	22.79	1.394	4.406	2.229	3.383	.923
	18.06	20.21	.570	5.074	1.157	-	-
		22.79	1.271	.921	1.868	1.790	1.639
		25.35	.298	7.978	2.173	3.784	1.109
	20.58	22.79	2.657	1.102	.959	1.161	1.816
1.17	15.91	26.83	-	1.888	1.720	1.297	.294
	18.72	21.07	1.029	-	.816	-	-
		23.95	.312	.377	1.913	3.240	2.131
		26.83	.203	7.078	2.205	3.822	1.847
	21.53	26.83	2.337	.838	3.492	4.650	2.189

Table 49. Marginal value of one additional hour of June-July hired labor by areas

Corn price	Pork price	Beef price	Area 1	2	3	4	5
($/bu)	($/cwt)	($/cwt)					
.93	14.88	23.60	1.33	6.89	1.79	4.01	3.40
	17.11	19.03	2.93	5.59	1.64	2.33	3.88
		21.32	2.45	8.25	2.57	3.42	7.91
		23.60	1.44	8.76	2.49	5.46	5.72
	19.34	23.60	2.67	9.73	.99	6.10	8.98
1.05	15.54	22.79	1.44	6.85	2.23	4.92	5.66
	18.06	20.21	3.14	6.28	1.16	-	9.35
		22.79	5.91	9.28	1.87	4.78	8.69
		25.35	5.73	9.11	2.17	3.71	3.83
	20.58	22.79	6.34	11.97	.96	7.22	13.18
1.17	15.91	26.83	4.41	6.96	1.72	2.14	2.46
	18.72	21.07	2.77	7.70	.82	.09	10.07
		23.95	5.31	9.19	1.65	3.21	8.18
		26.83	5.30	9.90	2.21	3.02	5.66
	21.53	26.83	3.04	11.66	3.32	1.83	11.20

Table 50. Marginal value of one additional hour of August-September hired labor by areas

Corn price	Pork price	Beef price	Area 1	2	3	4	5
($/bu)	($/cwt)	($/cwt)					
.93	14.88	23.60	.95	4.56	1.79	4.44	7.98
	17.11	19.03	1.17	1.87	3.07	2.02	7.20
		21.32	1.52	2.90	4.37	3.22	7.20
		23.60	1.61	3.04	3.02	6.22	7.86
	19.34	23.60	3.07	7.35	3.96	6.18	7.46
1.05	15.54	22.79	1.66	5.64	2.48	5.43	4.88
	18.06	20.21	2.54	2.86	2.51	3.05	7.26
		22.79	4.42	4.21	3.86	6.33	5.46
		25.35	2.94	4.02	3.26	5.65	11.50
	20.58	22.79	4.52	6.10	5.11	6.56	5.13
1.17	15.91	26.83	2.22	4.34	2.07	4.50	8.73
	18.72	21.07	5.10	3.97	3.60	5.00	1.79
		23.95	3.99	4.76	4.02	6.30	5.08
		26.83	3.78	4.12	3.54	5.87	7.94
	21.53	26.83	4.08	4.56	4.08	8.38	2.19

Table 51. Marginal value of one additional hour of October-November hired labor by areas

Corn price	Pork price	Beef price	Area 1	2	3	4	5
($/bu)	($/cwt)	($/cwt)					
.93	14.88	23.60	9.74	8.52	3.11	13.41	-
	17.11	19.03	7.31	7.81	5.20	16.59	-
		21.32	12.60	10.63	5.23	19.26	.19
		23.60	11.11	10.95	3.29	18.69	.56
	19.34	23.60	14.54	13.76	14.31	23.94	1.23
1.05	15.54	22.79	11.66	11.10	3.91	15.71	.92
	18.06	20.21	12.79	11.88	9.74	18.74	8.21
		22.79	16.03	14.58	11.50	22.34	1.64
		25.35	15.51	14.74	8.72	20.99	1.11
	20.58	22.79	14.05	16.77	17.54	26.94	1.82
1.17	15.91	26.83	13.06	12.32	6.41	15.90	.29
	18.72	21.07	15.39	16.54	13.93	21.33	-
		23.95	16.55	16.51	11.39	22.31	2.13
		26.83	16.29	14.83	9.29	21.81	1.85
	21.53	26.83	16.72	15.49	5.97	24.67	2.19

October-November period dominated the solutions, a much higher proportion of the labor hired was in the form of full-time labor so the maximum amount of labor could be obtained for use in the October-November period. It was possible, therefore, to have all of the labor for hire used as full-time labor and seasonal labor in the October-November period (see Table 43). Then there would not be any of the total labor constraint left to use in hiring seasonal labor in other periods. Thus, a positive shadow price for another period is possible even though no seasonal labor was hired in that period.

The shadow price values for labor by periods in each area vary a great deal. The highest values are for October-November labor in areas 1, 2 and 3. Some of these values are over $20.00 and most of them are over $10.00. Labor for June and July is generally quite restrictive in areas 2 and 5 and August-September labor has some high shadow price values in area 5.

3. Operating capital

Capital resources available for operating the farms can also be analyzed by looking at the quantities used and at the marginal value of additional capital. Tables 52-54 show the amount of operating capital used on each representative farm for each model solution. The highest capital use was on the beef farms. This was possible because 90 percent of the purchase value of feeder cattle was assumed to be mortgageable property. There was a significantly smaller amount of capital used on the beef farms when the fed cattle price was only $19.03.

The marginal value of one additional dollar of operating capital is shown in Tables 55-57. Operating capital was generally not a restrictive resource on the cash grain and dairy farms. The highest shadow price values are on the hog farms, numbers 12, 18 and 23.

Table 52. Average dollars of operating capital used on each representative farm when the price of corn is $.93

Pork price	14.88		17.11		19.34
Beef price	23.60	19.03	21.32	23.60	23.60
Representative farm number					
1	6,755	6,545	6,642	6,595	6,526
2	15,339	13,537	13,702	15,233	13,709
3	11,620	11,929	11,290	11,290	11,276
4	60,686	21,976	61,635	62,743	63,575
5	28,874	24,455	24,676	28,936	24,676
6	19,683	10,132	21,969	33,542	33,790
7	15,586	14,813	14,967	16,587	14,963
8	12,641	12,118	9,898	12,132	9,817
9	82,869	32,545	70,014	97,511	85,555
10	18,536	18,468	18,558	18,558	18,601
11	4,173	3,991	3,971	3,948	3,937
12	10,385	10,385	10,385	10,385	10,385
13	13,160	11,806	11,952	11,952	11,952
14	10,234	10,405	10,431	10,431	10,171
15	29,383	23,739	23,965	31,341	24,000
16	5,575	5,412	5,418	5,418	5,293
17	7,839	8,664	8,740	7,459	6,750
18	15,828	15,673	15,676	15,677	15,673
19	16,462	13,338	13,589	16,462	13,923
20	18,419	14,123	11,694	14,126	11,577
21	30,647	21,303	21,536	26,263	23,274
22	5,197	5,097	5,132	5,132	5,008
23	16,145	16,105	16,150	16,150	16,150
24	15,410	15,670	15,906	15,907	15,905
25	18,878	18,704	15,933	15,985	12,780
26	14,615	17,644	51,813	69,275	70,551
27	32,776	25,889	26,150	29,409	26,170

Table 53. Average dollars of operating capital used on each representative farm when the price of corn is $1.05

Pork price	15.54		18.06		20.58
Beef price	22.79	20.21	22.79	25.35	22.79
Representative farm number					
1	6,847	6,634	6,732	6,635	6,510
2	15,154	13,702	14,448	15,335	13,709
3	11,640	13,384	12,114	12,115	12,444
4	58,474	44,523	60,195	61,381	60,357
5	27,315	24,676	24,676	27,667	24,684
6	19,537	19,826	21,858	29,926	29,053
7	15,959	14,966	14,953	16,504	14,966
8	14,823	12,229	12,230	12,230	12,216
9	79,393	70,532	83,506	97,922	83,169
10	18,536	18,560	18,564	18,560	18,601
11	4,130	4,083	,4083	4,083	3,980
12	10,385	10,385	10,385	10,385	10,385
13	11,949	11,953	11,953	11,953	11,965
14	10,547	10,610	10,610	10,610	10,279
15	28,699	23,995	23,979	28,677	24,005
16	5,661	5,484	5,484	5,484	5,345
17	7,563	8,570	8,450	7,449	6,675
18	15,787	15,675	15,675	15,675	15,675
19	16,084	13,570	14,631	15,963	13,567
20	18,793	14,565	19,156	18,928	11,579
21	28,928	21,581	22,304	29,332	21,557
22	5,159	5,086	5,086	5,086	5,009
23	16,141	16,141	16,141	16,141	16,141
24	15,867	15,869	15,867	15,869	15,866
25	17,512	17,570	14,058	16,339	7,259
26	46,702	34,231	52,097	68,361	67,540
27	28,981	26,174	26,159	26,168	26,159

Table 54. Average dollars of operating capital used on each representative farm when the price of corn is $1.17

Pork price	15.91		18.72		21.53
Beef price	26.83	21.07	23.95	26.83	26.83
Representative farm number					
1	6,957	6,717	6,717	6,717	6,531
2	15,529	13,709	15,336	15,525	15,525
3	15,339	14,428	12,021	12,021	12,731
4	62,806	44,836	61,411	63,668	64,656
5	27,994	24,676	27,668	28,011	30,291
6	21,020	19,738	30,660	33,421	37,837
7	17,120	14,966	16,876	16,837	15,031
8	18,277	12,235	12,235	12,235	12,221
9	96,258	65,240	91,068	102,253	107,105
10	18,536	18,604	18,560	18,560	18,601
11	4,250	4,144	4,144	4,144	4,029
12	10,385	10,385	10,385	10,385	10,385
13	11,944	11,954	11,954	11,954	11,954
14	10,644	10,791	10,791	10,791	10,448
15	27,558	23,983	30,643	29,890	31,757
16	5,762	5,560	5,560	5,560	5,405
17	7,309	8,098	6,967	6,882	6,434
18	15,674	15,681	15,674	15,674	15,674
19	16,806	13,565	15,510	16,224	16,224
20	20,389	14,828	20,567	19,855	17,954
21	31,353	21,605	28,756	31,367	25,672
22	5,131	5,098	5,044	5,044	5,025
23	16,129	16,134	16,134	16,134	16,134
24	15,848	15,858	15,858	15,858	15,858
25	19,207	14,397	12,539	16,098	14,742
26	47,590	36,076	68,901	70,799	72,650
27	29,799	26,174	26,170	26,170	28,634

Table 55. Marginal value of one additional dollar of operating capital when the price of corn is $.93

Pork price	14.88	17.11			19.34
Beef price	23.60	19.03	21.32	23.60	23.60
Representative farm number					
1	-	-	-	-	-
2	.042	.499	.222	.284	.350
3	-	-	-	-	-
4	.004	-	.001	.118	.158
5	.055	.280	.155	.182	.284
6	-	-	-	.030	.073
7	-	.142	.083	.092	.183
8	.052	.016	-	-	-
9	-	-	-	.065	.109
10	.159	.350	.288	.294	.337
11	-	-	-	-	-
12	.386	.612	.612	.612	.847
13	.079	.199	.155	.219	.270
14	-	-	-	-	-
15	.115	.345	.259	.289	.329
16	-	-	-	-	-
17	-	-	-	-	-
18	.121	.280	.229	.240	.363
19	.040	.233	.127	.117	.213
20	-	-	-	-	-
21	.090	.254	.150	.237	.276
22	-	-	-	-	-
23	.330	.554	.554	.542	.774
24	-	.116	.116	.105	.292
25	-	-	-	-	-
26	-	-	-	.069	.112
27	-	.340	-	.083	.295

Table 56. Marginal value of one additional dollar of operating capital when the price of corn is $1.05

Pork price	15.54		18.06		20.58
Beef price	22.79	20.21	22.79	25.35	22.79
Representative farm number					
1	-	-	-	-	-
2	.037	.284	.094	.168	.436
3	-	-	-	-	-
4	.008	-	.026	.106	.104
5	.054	.270	.132	.175	.331
6	-	-	-	-	-
7	-	.108	.030	.069	.153
8	.004	.142	.042	.088	.027
9	-	-	-	.034	-
10	.172	.347	.205	.313	.369
11	-	-	-	-	-
12	.407	.597	.597	.607	.846
13	.083	.241	.203	.272	.289
14	-	-	-	-	-
15	.123	.338	.207	.267	.351
16	-	-	-	-	-
17	-	-	-	-	-
18	.119	.247	.184	.217	.339
19	.036	.232	.090	.133	.213
20	-	-	-	-	-
21	.092	.260	.142	.226	.307
22	-	-	-	-	-
23	.356	.545	.545	.543	.776
24	.046	.128	.187	.126	.394
25	-	-	-	-	-
26	-	-	-	.021	.003
27	-	.288	.090	.151	.153

Table 57. Marginal value of one additional dollar of operating capital when the price of corn is $1.17

Pork price	15.91		18.72		21.53
Beef price	26.83	21.07	23.95	26.83	26.83
Representative farm number					
1	-	-	-	-	-
2	.018	.161	.160	.177	.454
3	-	-	-	-	-
4	.046	-	.121	.150	.412
5	.078	.238	.198	.218	.529
6	-	-	-	.009	.157
7	-	.070	.071	.084	.236
8	.072	.162	.098	.137	.261
9	-	-	.031	.040	.197
10	.181	.287	.271	.357	.565
11	-	-	-	-	-
12	.382	.584	.607	.612	.850
13	.068	.158	.233	.281	.556
14	-	-	-	-	-
15	.133	.291	.290	.311	.599
16	-	-	-	-	-
17	-	-	-	-	-
18	.110	.211	.217	.230	.409
19	.065	.192	.135	.161	.360
20	-	-	-	-	-
21	.105	.230	.239	.267	.533
22	-	-	-	-	-
23	.335	.536	.549	.553	.788
24	.222	.412	.424	.428	.649
25	-	-	-	-	-
26	-	-	.027	.042	.216
27	.051	.222	.225	.252	.535

VI. ANALYSIS OF THE MODEL

The methodology and the model used in this study can be evaluated by considering the predictability of the empirical results. The first part of this chapter is devoted to a comparison of the empirical results with historical levels of production and with empirical supply response estimates from the Corn Belt regional adjustment study. The last part of this chapter is a discussion of the assumptions and particular features of the model, the effect they had on the empirical supply response estimates and the limitations of these model features.

A. Comparison of Supply Response Estimates

One way to evaluate the predictability of the empirical estimates of supply response for pork and beef in Iowa is to compare them with recently observed actual levels of production. This is a valid comparison if we assume that demand conditions for pork and beef in the model period of 1971-1973 will be similar to the demand for these products in the recent past and that Iowa farmers correctly anticipated the demand for their products in the recent past. Also, it must be assumed that producers outside the state of Iowa will continue to supply the same approximate percentages of the quantities of pork and beef needed as they have in the recent past.

The empirical estimates of supply response for pork and beef from this study were presented in Chapter V. It was pointed out that the programmed supply quantities of pork are from 3.32 up to 3.82 times as large as the annual average of 49,420 thousand hundred-weight of pork marketed from Iowa farms in 1966-1968. At the same time the programmed supply quantities of beef are .53 up to .98 of the average annual quantity of all cattle and calves (including dairy animals) marketed from Iowa farms in 1966-1968.

A more detailed comparison of the model results with historical observations is shown in Table 58. The first model solution shown is the solution that came the closest to estimating the historical levels of supply. The pork-corn price ratio is significantly less than the historical ratio and the beef-corn price ratio is significantly higher than the historical ratio.

The second, third and fourth model solutions shown are those that had the pork-corn, the beef-corn and the beef-pork price ratios closest to the historical ratios respectively.

Another way to evaluate the model used in this study is to compare the estimates of supply response for pork and beef with similar estimates made by using different methodology in the Corn Belt regional adjustment study. The aggregate

Table 58. Comparison of programmed aggregate supply response for Iowa and recent historical levels of production

Source of data	Corn price	Price ratios			Livestock production	
		Pork: corn	Beef: corn	Beef: pork	Pork	Beef
	($/bu)				(1,000 cwt)	(1,000 cwt)
Historical	1.15[a]	17.9:1[a]	20.3:1[a]	1.131:1[a]	49,420	49,789
Model	1.17	13.6:1	22.9:1	1.686:1	163,893	49,186
Model	1.05	17.2:1	21.7:1	1.262:1	178,993	35,728
Model	1.17	16.0:1	20.5:1	1.279:1	171,980	48,623
Model	1.17	16.0:1	18.0:1	1.127:1	182,105	26,375

[a]The historical prices used are the average for 1965-1967 based on the naive assumption that the price in year t is the producer's expected price for year t + 1.

supply response estimates for the early 1970's from the regional adjustment study were a summation of the estimates of supply from representative farm programming models that were assumed to be independent of each other. The operator of each representative farm could produce any quantity of the products that he chose to produce within the limit of his resources and could buy whatever quantities of hired labor, feeder cattle and feed grains he needed.

Data from seven of the twenty-seven linear programming solutions used in the regional adjustment study are shown in Table 59. The first solution shown is at the medium prices for corn, pork and beef. A comparison of the supply estimates with the medium prices in the current study show that the quantity of hogs is 2.1 times higher in the regional adjustment study even though the pork-corn price ratio is significantly lower. The beef quantity estimates are very close to each other and the beef-corn price ratios are also quite close.

The next three solutions in Table 59 were chosen because the beef-pork price ratio of 1.124:1 is close to the low end of the beef-pork price relationship considered in this study. The results from the regional adjustment study show estimated quantities of pork from 2.0 to 2.2 times higher than in the current study while estimated quantities of beef were only .07 or less of the estimates from this study.

Table 59. Partial results for Iowa from the Corn Belt regional adjustment study[a]

Corn price	Price ratios			Livestock production		Corn imported
	Pork: corn	Beef: corn	Beef: pork	Pork	Beef	
($/bu)				(1000 cwt)	(1000 cwt)	(1000 bu)
1.00	14.8:1	20.8:1	1.405:1	372,191	35,454	1,381,827
.80	18.5:1	20.8:1	1.124:1	404,208	1,850	1,440,022
1.00	14.8:1	16.6:1	1.124:1	394,276	778	1,322,391
1.20	12.3:1	13.9:1	1.124:1	366,537	0	1,153,447
.80	18.5:1	31.2:1	1.686:1	231,721	323,057	2,033,101
1.00	14.8:1	25.0:1	1.686:1	233,412	199,109	1,477,929
1.20	12.3:1	20.8:1	1.686:1	194,868	203,052	1,258,600

[a]Source (9).

The last three solutions are when a beef-pork ratio of 1.686:1 is used. This is the same as the 1.686:1 ratio used in the current study when the price of pork was $15.91 while the price of beef was $26.83. At this relationship of beef and pork prices the estimated quantities from the regional adjustment study were from 1.2 to 1.4 times higher for pork and 4.0 to 6.6 times higher for beef.

The estimates of quantities of pork from the regional adjustment study are, therefore, significantly higher than the estimates from this study. The supply quantity estimates for beef from the regional adjustment study vary from significantly less to significantly more than in the current study. Both the pork and beef estimates from the regional adjustment study have a wide range as the beef-pork price relationship goes from 1.124:1 to 1.686:1. The quantity of pork more than doubles from 194,868 thousand hundred-weight to 404,208 thousand hundred-weight while the quantity of beef increases infinitely from zero to 323,057 thousand hundred-weight.

These wide ranges in the quantities of beef and pork produced imply one of the additional results in the regional adjustment study. The individually programmed representative farms had similar patterns of production and had large shifts in the products they produced. When the beef-corn price ratio was low they were all specialized hog farms and when the beef-corn price ratio was high most were specialized beef farms. There was no diversity between farms in their pattern of production and there were never any cash grain farms.

One other interesting result from the regional adjustment study is the large quantities of corn imported into the state. For the seven solutions shown in Table 59 more corn was imported than has been produced in Iowa in any recent year. Corn was imported into Iowa in twenty-six of the twenty-seven model solutions for the regional adjustment study. Only when the pork-corn price ratio was 9.9:1 and the beef-corn price ratio was 13.9:1 was Iowa a net exporter of corn.

B. Evaluation of the Assumptions and Features of the Model

The general assumptions that must be kept in mind when interpreting the results from this study were listed at the beginning of Chapter V. Those that will be discussed and evaluated here are the objective function, the perfectly elastic demand for products, the interaction among farms to buy and sell feed grains and hay, the endogenous factor supply functions for hired labor and feeder cattle, the type-of-farm constraint and the minimum income equation.

1. The assumption of profit maximization under perfect knowledge

A basic assumption of a linear programming model is that all producers have perfect knowledge and the single common objective function of profit maximization. This is, of course, not the "real world" situation faced by producers. They do not have perfect knowledge of what the production situation or production costs will be, what the prices received will be for their products, etc. Producers are also known to exhibit many other objectives in production such as risk minimization, maintenance of a minimum level of income, minimization of labor use at certain times of the year or in total, etc.

The advantages gained from using a linear programming model are, howver, more than sufficient to make linear programming an important and valuable research technique to use in analyzing supply response. The flexibility to consider different levels of aggregation, to consider new policy variables on which there is no historical observation and to consider different economic lengths-of-run is a primary reason that makes the technique valuable in supply response research.

2. The assumption of a perfectly elastic demand for products

The single most damaging assumption (in terms of the predictiveness of the empirical results) is that Iowa farmers can market all of a product they produce at a constant price. Although this is a realistic assumption for a single producer it is not realistic for the aggregate of producers.

The effect of a downward sloping aggregate demand function for pork and beef must be considered in the model if the empirical results are to be more predictive. The supply response by a producer is conditioned by the expected aggregate demand conditions for his products in the same manner that his supply response is conditioned by the limit on resources available to the aggregate of firms. In fact, a farmer is probably more aware of the fact that an increase in production on his farm may drive the product price downward because other producers are also increasing production than he is aware that his purchase of more inputs in the form of hired labor and feeder cattle will force his cost of production upward.

3. <u>The interaction among farms to buy and sell feed grains and hay</u>

One of the features of the interfirm competition model used in this study is the direct transfer of feed grains and hay between farms. The direct transfer serves to limit the quantity of feed grains available to the aggregate of the firms since it is assumed that Iowa will at least be self sufficient in the production of feed grains. The direct transfer method also limits the quantity of hay that can be purchased by a farm to the quantity that some other farm in the same area will sell.

This method is opposed to the regional adjustment study model where individual firms could buy or sell feed grains and hay in unlimited quantities. When the representative farms were programmed independently, there was no realistic way to limit the amount of feed grains any one farm could purchase. Because there was no limit, the summation of the quantity of feed grain purchased by each farm showed that Iowa (and the other North Central states included in the Corn Belt regional adjustment study) was a major importer of feed grains at most of the prices for corn, pork and beef.

It is obvious that the interaction among farms to transfer feed grains and hay directly between farms is a feature of the interfirm competition model that makes it an improvement over the regional adjustment study model. The aggregate limit on feed grains reduced total livestock production below the estimated production in the regional adjustment study. If the representative farms in this study were programmed individually, the cash grain farms would sell feed grains because of the type-of-farm constraint. There would be no method, however, to limit the other farms to purchasing only the amount of feed grains sold from the cash grain farms and the aggregate result would again be quantities of feed grain imported into Iowa.

Table 60 shows the bushels of corn that were sold from the farms on which it was produced. The quantity sold increased slightly as the price of corn increased from \$.93 to \$1.05 and also as the price of corn increased to \$1.17.

Table 60. Total bushels of corn sold from the farms where it was produced

Corn price	Pork price	Beef price	Area of state 1	2	3	4	5	State Total
($/bu)	($/cwt)	($/cwt)	(1000 Bu)	(1000 Bu)	(1000 Bu)	(1000 Bu)	(1000 Bu)	(1000 Bu)
.93	14.88	23.60	160,512.9	46,689.8	105,197.0	164,412.2	17,839.8	494,651.7
	17.11	19.03	178,614.7	41,080.8	84,945.2	115,614.5	16,931.7	437,186.9
		21.32	167,848.8	34,600.2	85,070.2	100,491.6	18,813.8	406,824.6
		23.60	169,157.6	40,850.5	105,202.0	104,223.5	19,130.2	438,563.8
	19.34	23.60	176.375.7	36,784.5	86,812.5	86,714.1	14,277.1	400,963.9
1.05	15.54	22.79	159,447.8	51,728.5	98,250.4	171,892.9	15,497.6	496,817.2
	18.06	20.21	194,199.7	42,161.7	84,718.7	121,908.1	20,528.6	463,516.8
		22.79	174,713.6	41,807.0	98,838.4	142,917.2	15,455.8	473,732.0
		25.35	177,442.7	41,804.1	105,305.5	166,464.6	17,270.9	508,287.8
	20.58	22.79	191,517.7	44,453.2	85,891.6	90,142.9	10,367.7	422,373.1
1.17	15.91	26.83	183,365.2	59,457.3	98,478.8	181,404.5	13,173.2	535,879.0
	18.72	21.07	209,066.5	41,013.8	101,720.3	119,309.8	15,480.1	486,590.5
		23.95	178,939.8	41,013.8	108,944.7	159,398.7	12,264.5	500,561.5
		26.83	178,939.8	41,013.8	108,496.2	161,712.9	13,388.7	503,551.4
	21.53	26.83	196,446.4	43,653.9	104,341.1	144,721.8	13,899.8	503,063.0

The next three tables 61-63, show the corn sales by each aggregated representative farm. Most of the corn sold was from cash grain farms. These were farm numbers 1, 3, 8, 11, 14, 16, and 20. The dairy farms, numbers 17, 22 and 25 sold some corn also.

4. The endogenous factor supply functions

Another feature of the interfirm competition model is the endogenous factor supply functions for hired labor and feeder cattle. Discontinuous points on these upward sloping functions were included in the model to limit the quantities of labor for hire and feeder cattle that are available to the aggregate of firms and also to allow for the possibility of external pecuniary diseconomies.

The labor for hire factor supply function served to effectively limit the total amount of labor that the aggregate of farms hired in each model solution. It is not possible, however, to evaluate the usefulness of the upward sloping function in allowing for the possibility of external pecuniary diseconomies. The reason is that all available labor for hire was hired in each of the model solutions. The 46,123,000 hours of labor for hire at the point where the wage rate is $3.00 per hour and the factor supply function becomes perfectly inelastic were hired in each solution.

The feeder cattle factor supply function also limited the quantity of feeder cattle purchased in about one-half of

Table 61. Bushels of corn sold from the aggregated representative farms when the price of corn is $.93

Pork price	14.88	17.11			19.34
Beef price	23.60	19.03	21.32	23.60	23.60
	(1000 bu)	(1000 bu)	(1000 bu)	(1000 bu)	(1000 bu)
Representative farm number					
1	98,427.5	100,690.8	98,558.1	99,866.9	99,344.4
2	-	-	-	-	-
3	62,085.4	77,923.9	69,290.7	69,290.7	77,031.3
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-
7	-	-	-	-	-
8	40,250.4	41,080.8	34,600.2	40,850.5	36,784.5
9	-	-	-	-	-
10	6,439.4	-	-	-	-
11	16,383.5	17,345.9	17,470.9	17,595.5	18,115.2
12	-	-	-	-	-
13	-	-	-	-	-
14	65,869.2	67,599.3	67,599.3	67,599.3	68,697.3
15	22,944.3	-	-	20,007.2	-
16	26,984.0	27,558.2	27,558.2	27,558.2	28,015.9
17	8,579.1	19,165.6	19,165.6	8,606.2	-
18	-	-	-	-	-
19	-	-	-	-	-
20	85,705.1	68,890.7	53,767.8	68,059.1	58,698.2
21	43,144.1	-	-	-	-
22	5,249.5	5,323.0	5,323.0	5,323.0	4,512.5
23	-	-	-	-	-
24	-	-	-	-	-
25	12,590.3	11,454.0	13,490.8	13,807.2	9,764.6
26	-	-	-	-	-
27	-	154.7	-	-	-

Table 62. Bushels of corn sold from the aggregated representative farms when the price of corn is $1.05

Pork price	15.54		18.06		20.58
Beef price	22.79	20.21	22.79	25.35	22.79
	(1000 bu)	(1000 by)	(1000 bu)	(1000 bu)	(1000 bu)
Representative farm number					
1	97,335.5	99,867.1	97,093.7	99,865.4	100,642.0
2	-	-	-	-	-
3	62,112.3	94,332.6	77,619.9	77,577.3	90,875.7
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-
7	-	-	-	-	-
8	45,311.8	42,161.7	41,807.0	41,804.1	44,453.2
9	-	-	-	-	-
10	6,416.7	-	-	-	-
11	17,059.7	17,672.5	17,672.5	17,672.5	17,983.7
12	-	-	-	-	-
13	-	-	-	-	-
14	64,650.8	67,046.2	67,046.2	67,046.2	67,907.9
15	16,539.9	-	14,119.7	20,586.8	-
16	26,670.0	27,316.7	27,316.7	27,316.7	27,825.0
17	8,598.8	23,891.1	22,837.7	13,978.9	3,511.3
18	-	-	-	-	-
19	-	-	-	-	-
20	87,874.6	70,700.3	92,762.8	91,667.2	58,806.6
21	48,749.5	-	-	33,501.8	-
22	5,292.6	5,162.1	5,162.1	5,162.1	4,854.2
23	-	-	-	-	-
24	-	-	-	-	-
25	10,205.0	15,212.3	10,293.7	12,108.8	5,513.5
26	-	-	-	-	-
27	-	154.2	-	-	-

Table 63. Bushels of corn sold from the aggregated representative farms when the price of corn is $1.17

Pork price	15.91	18.72			21.53
Beef price	26.83	21.07	23.95	26.83	26.83
	(1000 bu)	(1000 bu)	(1000 bu)	(1000 bu)	(1000 bu)
Representative farm number					
1	96,021.8	98,884.3	98,884.3	98,884.3	101,099.1
2	-	-	-	-	-
3	87,343.4	110,182.2	80,055.5	80,055.5	95,347.3
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-
7	-	-	-	-	-
8	53,017.8	41,013.8	41,013.8	41,013.8	43,653.9
9	-	-	-	-	-
10	6,439.4	-	-	-	-
11	17,233.0	17,487.1	17,487.1	17,487.1	17,837.1
12	-	-	-	-	-
13	-	-	-	-	-
14	64,395.0	66,347.3	66,347.3	66,347.3	67,666.9
15	16,850.8	17,885.9	25,110.3	24,661.8	18,837.1
16	26,302.5	27,037.8	27,037.8	27,037.8	27,606.8
17	11,968.7	20,506.4	11,975.5	3,479.9	-
18	-	-	-	-	-
19	-	-	-	-	-
20	91,637.3	71,765.6	94,115.3	92,091.0	86,703.0
21	51,496.0	-	26,270.1	39,104.2	30,412.0
22	5,322.8	5,218.3	4,993.9	4,993.9	4,952.7
23	-	-	-	-	-
24	-	-	-	-	-
25	7,850.4	10,107.6	7,270.6	8,394.8	8,947.1
26	-	-	-	-	-
27	-	154.2	-	-	-

the fifteen model solutions. In the other solutions the number of feeder cattle purchased was on the portion of the factor supply function that was assumed to be perfectly elastic before the function became upward sloping.

A major problem with the factor supply function for feeder cattle is that it allows an important price relationship to be inconsistent. This is the relationship between the price of feeder cattle and the price of fed cattle. Historically, this is a rather stable relationship, the mean ratio of feeder cattle-fed cattle prices from 1957 to 1968 being 1.1248:1 with a standard deviation of only .068. Over the twelve year period this price ratio was always greater than 1.0.

The result of including the factor supply function in the model was that the feeder cattle-fed cattle price ratio programmed ranged from only .745:1 up to 1.051:1. A direct tie between the two prices was not required in the model.

A more useful method to consider the factor supply function for feeder cattle in the model would be to use the method used by Berry (3) in combination with part of the procedure used in this model. Berry estimated the price of feeder cattle as a function of the price of fed cattle, pork, and feed grains. This estimated price for feeder cattle was used in Berry's model along with the corresponding combination of product prices. But, rather than consider the factor supply function perfectly elastic at the estimated price as

Berry did, the price-quantity loci from the factor supply function estimated for this model could be used as a single constraint in the model. This would limit the quantity of feeder cattle that could be purchased by the aggregate of firms but also maintain a consistent relationship between the prices of feeder cattle and fed cattle.

5. <u>The type-of-farm constraint</u>

A gross sales accounting equation was used in the sub-model for each specialized representative farm to restrict the products sold to those that would retain the farm type definition. This feature could be included if each farm was programmed separately as well as in an aggregate model.

Table 64 gives the shadow price values for the type-of-farm constraint on each specialized farm in each solution. The constraint was never binding on the hog farms but it did restrict the profit-maximizing livestock activities on the cash grain farms and restricted hog production on the beef and dairy farms.

The type-of-farm constraint was restrictive on the cash grain farms in all solutions except farm number 8 for one solution. The shadow price values went higher, of course, when the pork-corn and beef-corn price ratios were increased. The marginal value from relaxing the type-of-farm constraint by $1 on the cash grain farms ranged from 0 up to .355 except for three solutions where it was higher on farm 11.

Table 64. Marginal effect of relaxing the type-of-farm constraint by $1 on the specialized farms

Corn price	Pork price	Beef price	Representative farm number								
			1	3	4	6	8	9	11	12	14
($/bu)	($/cwt)	($/cwt)									
.93	14.88	23.60	.186	.042	.006	-	.002	-	.284	-	.151
	17.11	19.03	.273	.120	.203	.263	.112	.167	.706	-	.223
		21.32	.273	.146	.087	.098	.082	.050	.670	-	.223
		23.60	.273	.155	.014	-	.084	-	.588	-	.241
	19.34	23.60	.347	.241	.044	.014	.156	.006	.347	-	.295
1.05	15.54	22.79	.203	.049	.003	.008	.019	-	.203	-	.163
	18.06	20.21	.269	.085	.158	.231	.033	.125	.269	-	.187
		22.79	.269	.067	.037	.048	.017	-	.269	-	.173
		25.35	.274	.079	.020	-	.025	-	.274	-	.199
	20.58	22.79	.348	.155	.088	.092	.094	.062	.348	-	.234
1.17	15.91	26.83	.198	.020	-	-	-	-	.198	-	.135
	18.72	21.07	.270	.046	.131	.205	.001	.089	.270	-	.160
		23.95	.282	.083	.025	-	.025	-	.282	-	.191
		26.83	.284	.088	.019	.004	.020	-	.284	-	.209
	21.53	26.83	.355	.212	-	-	.068	-	.355	-	.310

Table 64 (Continued)

Corn price	Pork price	Beef price	Representative farm number							
			16	17	18	20	22	23	25	26
($/bu)	($/cwt)	($/cwt)								
.93	14.88	23.60	.186	.172	-	.026	.066	-	.188	.034
	17.11	19.03	.273	.322	-	.116	.163	-	.347	.271
		21.32	.273	.322	-	.102	.163	-	.443	.127
		23.60	.273	.322	-	.081	.162	-	.462	.038
	19.34	23.60	.347	.398	-	.161	.252	-	.591	.073
1.05	15.54	22.79	.203	.185	-	.019	.097	-	.328	.029
	18.06	20.21	.269	.460	-	.093	.221	-	.477	.229
		22.79	.269	.342	-	.039	.221	-	.625	.078
		25.35	.274	.349	-	.064	.221	-	.573	.047
	20.58	22.79	.348	.409	-	.107	.298	-	.605	.133
1.17	15.91	26.83	.198	.223	-	.028	.133	-	.355	.033
	18.72	21.07	.270	.460	-	.067	.246	-	.603	.213
		23.95	.282	.370	-	.069	.243	-	.587	.050
		26.83	.284	.365	-	.076	.242	-	.563	.045
	21.53	26.83	.355	.420	-	.161	.324	-	.634	.037

The shadow prices for this constraint on the dairy farms were always positive, ranging from .066 to .634. For the beef farms, the type-of-farm constraint was not restrictive in several of the solutions that had a high beef-pork price ratio. The equation was instrumental in preventing the estimated quantities of beef from being lower in the solutions that had a low beef-pork price ratio. In several of these solutions almost all of the beef was produced on the specialized beef farms.

The type-of-farm equation is useful to typify the farm production organization based on historical data. It also is useful in narrowing the ranges over which the empirical estimates of pork and beef supplied will move. The estimates from this model do not vary nearly as widely as did the estimates from the Corn Belt regional adjustment study. The lower limit forced on beef production by the type-of-farm equation when the beef-pork price ratio is low also helps to keep the estimates of pork production from moving upward more sharply.

6. <u>The minimum returns equation</u>

An equation included in each representative farm sub-model required that the returns above variable costs be sufficient to pay fixed costs. This constraint generally did not restrict the products to be produced. Only on farm number 11 and when the price of corn was $.93 did this equation have a positive shadow price.

VII. SUMMARY AND SUGGESTIONS FOR FUTURE RESEARCH

Intelligence on supply response is an important commodity for agricultural policy makers, for agricultural input suppliers and for agricultural producers. Researchers in agricultural production economics have realized this need for information and have undertaken many important studies that have added to the body of knowledge on supply response.

A. The Problem and the Objectives

Even though formal research techniques have replaced more subjective methods, many practical problems still face the researcher who wants to derive empirical estimates of supply response. A method to functionally relate supply response by firms to supply response by the industry has not been developed. Models that have used linear regression techniques on time series data are primarily useful only for short-run estimates of supply response and only at a high level of aggregation. New policy variables that may affect supply response cannot be incorporated into regression models because there are no historical observations on the new variables.

Models that use mathematical programming techniques have added a great deal to supply response intelligence. However, the empirical estimates of supply response from these models have had a low predictive value, often being very different than historical supply quantities.

This study was undertaken with several specific objectives in mind that were believed to be useful additions to research techniques used in supply response studies. These objectives were:

(1) to develop a supply response model that will functionally relate firm and aggregate supply response.

(2) to include in the model some additional methods to reduce specification and aggregation error.

(3) to estimate the supply response for pork and beef in the state of Iowa to test the feasibility of the model.

(4) to analyze the empirical results obtained as a means of evaluating the proposed methodology, and to draw out economic implications for the area studied.

B. The Conceptual and Empirical Models

The conceptual model contains several features designed to fulfill the objectives of the study. Representative farms are used as sub-models of an aggregate state model to functionally relate the supply response of firms to the supply response by the aggregate of firms. The quantities of inputs such as labor for hire, feeder cattle, feed grains and hay are limited to the aggregate of firms. The firms must compete for these inputs so the supply response by firms is conditioned by the combined actions of all firms.

Sources of specification error must be considered when enterprise budgets are constructed. The technical coefficients should be those that are expected to exist on each representative farm during the calendar period the model is to represent. The production functions are also dependent on the expected size of enterprises to try to maintain internal consistency in the model.

The resource structure on each representative farm should represent the same calendar period the production functions represent. This is another requirement of the conceptual model to minimize specification error.

The primary feature of the conceptual model to reduce aggregation error is to restrict the change in type classification for specialized farms. This feature captures the observed trend toward more specialization in farming and brings the effect of specialization to bear on the estimates of supply response.

Iowa farms were stratified by area, size and type to obtain twenty-seven representative farms to use in the empirical model. A linear programming model was constructed for each representative farm using the estimated resource structure for 1971-1973 as the limit on resource use, and cost and return estimates for production activities that also were consistent with the 1971-1973 calendar period.

The twenty-seven farm models were used as sub-models in one large linear programming matrix for the state. The farms could buy and sell feed grains and hay but the total quantity of feed grain available to all farms was limited to the quantity produced in the state. The quantity of hay available for purchase was limited to the amount produced in each area of the state.

The farms could also compete with each other for the aggregate supply of hired labor and feeder cattle. These inputs were entered into the state model as discontinuous points on estimated upward sloping factor supply functions to allow for the effects of external diseconomies on aggregate supply response.

Prices of corn, pork and beef were varied to estimate points on supply functions for pork and beef. The preselected product prices were chosen to be consistent with the historically observed price for corn and the historically observed price ratios for pork-corn, for beef-corn and for beef-pork.

C. The Empirical Supply Response Estimates and Analyses of the Model

When compared with recent historical quantities of pork and beef produced in Iowa, the supply response estimates derived from the model were not completely satisfactory. The model estimates were over three times too high for pork and were sometimes too low for beef but with estimates at some price combinations that were close to observed quantities for beef. The model assumption that the demand for products produced by all Iowa farmers is perfectly elastic is the most damaging assumption leading to the estimates of supply that are not satisfactory empirical predictions.

Supply response estimates for pork and beef in Iowa were also derived in the Corn Belt regional adjustment study completed in 1967. The model used in the current study was a significant improvement over the independent representative farm model used in the regional adjustment study. The interfirm competition model used in this study provided a way to effectively limit the quantity of feed grains that could be used for livestock production in Iowa and to limit the quantity of labor that could be used for all production activities. The result was lower estimates of supply response for pork from the interfirm competition model, generally less than half of the quantity of pork estimated in the regional adjustment study.

The estimates of supply quantities of beef from the interfirm competition model are more nearly "in the ball park" at all of the programmed product price combinations then they were in the regional adjustment study. The requirement that specialized beef farms must continue to produce beef even at low beef prices prevented the estimated supply quantity of beef from dropping to zero as it did in the regional adjustment study. The factor supply function for feeder cattle included in the interfirm competition model effectively placed an upper limit on the estimated supply quantity of beef when the programmed price of beef was high. When the beef-pork price ratio was 1.686:1 the estimated supply quantity of beef from the regional adjustment study ranged as high as 323,057 thousand hundred-weight compared to an estimate of 49,186 thousand hundred-weight from the interfirm competition model.

The features of the interfirm competition model used in this study were an improvement over the regional adjustment study model in yet another way. A comparison of the net supply response measures shows that the estimates of "elasticity" of aggregate supply are much lower in the interfirm competition model. They were more nearly comparable to estimates of supply elasticity derived from regression models.

D. Suggestions for Future Research

The interfirm competition model is an improvement in methodology that can be used to derive empirical estimates of supply response. However, the use of the interfirm competition model in this study suggests needed improvements and refinements. These suggestions are divided into the general areas of data needs and model refinements.

1. <u>Data needs</u>

Although the best data available were used in the model, there are some data problems. These problems revolve around the stratification scheme that requires data by area, size and type of farm. Information to differentiate the land resources by sizes and types of farms was rather sketchy. The data that were used to differentiate the land resources and to determine labor resources by type of labor on farms of different sizes and types in different areas are only a cross-section observation that is quickly becoming outdated.

The data needed to estimate livestock facilities on farms is virtually non-existent. Any estimate of capital resources is dependent on some very broad assumptions. In general, more detailed and up-to-date information on resources found on Iowa farms is needed.

Available data is also a problem in determining production cost differences for sizes and types of farms and for specialized enterprises. The cost differentials used in this model had to be primarily based on assumptions rather than data.

2. Model refinements

The interfirm competition model can be used to answer several types of questions. The changes that could be made to improve the model are dependent on what types of questions are to be answered.

a. Empirical estimates of supply response

One change that should be made in the interfirm competition model if it is to be used again to derive empirical estimates of supply response is to modify the factor supply function for feeder cattle. A consistent relationship should be maintained between feeder cattle prices and fed cattle prices at all times. The consistent feeder cattle price can then be used along with the estimated factor supply function to determine the maximum quantity of feeder cattle that can be purchased for that model solution.

Another model change that should be considered is to incorporate an accurate product demand relationship. This may require an iterative procedure to determine equilibrium quantities or it may be possible to incorporate a downward sloping product demand function in a manner similar to the one used to include upward sloping factor supply functions.

b. A consistency model

The interfirm competition model could also be used successfully to examine the implied changes in resource structure and resource mix on Iowa farms by changing it to a "consistency" model. Institutional limits could be included in the model that would limit the range over which important variables can move without damaging the specification of the model. Then if the relative resource relationships are properly specified in the model, an optimal solution to the model that is subject to the newly incorporated institutional limits would provide valuable information and implications on changes in resource use.

An example of an institutional limit to maintain the model specification would be maximum constraints on the quantity of pork that can be produced on each representative farm. These constraints could be set at the levels that maintained internal consistency with the assumed production functions. This would limit hog production in Iowa to not more than 4,571,385 litters a year.

c. A short-run policy model Some additional types of questions that could be investigated with an interfirm competition model are policy questions of a short-run nature. For example, questions concerning the effectiveness of feed grain program variables proposed for year t + 1 or t + 2 could be examined with an interfirm competition model.

Model changes needed for answering the short-run policy questions include using short-run supply elasticities for endogeneous input supply functions and exogenously estimating livestock production for the state and using these limits in the model. Also, other rigidities in short-run production should be incorporated in the model along with the restriction on change of farm types. These additional restraints may be nothing more than flexibility restraints that limit changes in quantities produced from one year to the next based on a historical amount of change. These flexibility restraints incorporate the producers' exhibited inertia toward change into the model. Questions on rates of diversion, levels of diversion payments, and basic structure of the feed grain program can then be evaluated. Also, questions on the side effects of the feed grain program on soybean production, on livestock production and on changes in the mix of resources can be investigated.

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X. APPENDIX A: ESTIMATION OF NUMBERS AND SIZES OF FARMS

The three level stratification scheme explained in Chapter IV was used to select the representative farms to include in the model. The twenty-seven chosen farms are found in five areas of the state, are divided into two size categories and are further divided into five types of farms.[1]

Two primary sources of data are available to use in analyzing the numbers, sizes and types of farms in Iowa. The Census of Agriculture gives an enumeration of the characteristics of Iowa farms at five year intervals. The 1964 and 1966 ERS Pesticide Use Surveys also contain information on numbers, sizes and types of farms. About 800 questionnaires were obtained in Iowa for each survey.

It was necessary to dovetail the information from these two data sources to determine what representative farms should be used in the model. The Census of Agriculture provides information on acres of farmland in farms of various sizes in the different areas of the state and on numbers of cash grain and dairy farms by areas. Additional information needed from the ERS Pesticide Use Surveys includes the proportions of the cash grain and dairy farms found in each area that are large farms or small farms, the percent

[1] See Table 1 for a list of the twenty-seven representative farms and their stratification characteristics.

of the farms in each area-size category that meet the definition of a specialized hog or specialized beef farm and the size differentials for the types of farms in each area.

Once the twenty-seven representative farms were chosen, the two data sources were used to estimate the average size of each representative farm and the number of farms being represented in the 1971-1973 calendar period the model represents. The notation used in estimating these two data items was as follows:

subscripts: i = 1, 2, 3, 4, 5 for the areas

j = 1, 2 for the sizes (1 = 1-259 acres and 2 = 260 acres or more)

k = 1, 2, 3, 4, 5 for the types (1 = cash grain, 2 = dairy, 3 = hog, 4 = beef and 5 = general)

. = summed across the corresponding subscript

superscripts: none = data from the Census of Agriculture

' = data from the 1964 and 1966 ERS Pesticide Use Survey

* = final estimate of a variable for the 1971-1973 calendar period

other: $\hat{}$ = estimated for 1972, generally a time series projection when used for exogenous variables

The variables and the identification of the exogenous variables estimated from the two data sources are:

A = acres

$\hat{A}_{...}$ = acres in farmland in Iowa

P = proportion

$\hat{P}_{ij.}$ = proportion of land in area i that is in size category j

$P_{i..}$ = proportion of land in state that is in area i

P'_{ij1} = proportion of cash grain farms in area i that are in size category j

P'_{ij2} = proportion of dairy farms in area i that are in size category j

P'_{ij3} = proportion of farms in area i and of size j that are hog farms

P'_{ij4} = proportion of farms in area i and of size j that are beef farms

C = average size

$\hat{C}_{ij.}$ = average size of farms in area i and of size j

C'_{ijk} = average size of farms in area i of size j and type k

$C'_{ij.}$ = average size of farms in area i and of size j

N = number of farms

$\hat{N}_{i.1}$ = number of cash grain farms in each area

$\hat{N}_{i.2}$ = number of dairy farms in each area

I = specialization index

I = annual change in the percent of farms in Iowa that are classified as specialized farms (cash grain, dairy, poultry, fruit and nut, vegetable and other field crop)

The equations used to estimate the average size of each representative farm and the number of farms being represented are:

$$\text{(F.1)} \quad \hat{A}_{i..} = (\hat{A}_{...})\ (P_{i..})$$

$$\text{(F.2)} \quad \hat{A}_{ij.} = (\hat{A}_{i..})\ (\hat{P}_{ij.})$$

$$\text{(F.3)} \quad \hat{P}'_{ij3} = (P'_{ij3})\ (I)$$

$$\text{(F.4)} \quad \hat{P}'_{ij4} = (P'_{ij4})\ (I)$$

$$\text{(F.5)} \quad R'_{ijk} = \frac{C'_{ijk}}{C'_{ij.}}$$

$$\text{(F.6)} \quad \hat{N}_{ij1} = (\hat{N}_{i.1})\ (P'_{ij1})$$

$$\text{(F.7)} \quad \hat{N}_{ij2} = (\hat{N}_{i.2})\ (P'_{ij2})$$

$$\text{(F.8)} \quad N^*_{ij1} = \hat{N}_{ij1}$$

$$\text{(F.9)} \quad N^*_{ij2} = \hat{N}_{ij2}$$

(F.10) $A^*_{ij1} = [N^*_{ij1}][(\hat{C}_{ij.})(R'_{ij1})]$

(F.11) $A^*_{ij2} = [N^*_{ij2}][(\hat{C}_{ij.})(R'_{ij2})]$

(F.12) $A^*_{ij3} = (\hat{A}_{ij.})(\hat{P}'_{ij3})(R'_{ij3})$

(F.13) $A^*_{ij4} = (\hat{A}_{ij.})(\hat{P}'_{ij4})(R'_{ij4})$

(F.14) $A^*_{ij5} = \hat{A}_{ij.} - (A^*_{ij1} + A^*_{ij2} + A^*_{ij3} + A^*_{ij4})$

(F.15) $N^*_{ij3} = \dfrac{A^*_{ij3}}{(\hat{C}_{ij.})(R'_{ij3})}$

(F.16) $N^*_{ij4} = \dfrac{A^*_{ij4}}{(\hat{C}_{ij.})(R'_{ij4})}$

(F.17) $N^*_{ij5} = \dfrac{\hat{A}_{ij.}}{\hat{C}_{ij.}} - (N^*_{ij1} + N^*_{ij2} + N^*_{ij3} + N^*_{ij4})$

(F.18) $C^*_{ijk} = \dfrac{A^*_{ijk}}{N^*_{ijk}}$

The implied assumptions behind this method of estimating the number and size of farms are:

(1) The observed historical trend in changes in farm size will continue.

(2) The observed historical trend in changes in the number of cash grain farms and the number of dairy farms will continue.

(3) The observed historical trend in the total land in farms will continue.

(4) The proportion of farmland that is in each area of the state will be the same as in 1964.

(5) The proportions of cash grain farms in each area that are small farms or large farms will be the same as the average proportions for 1964, 1966.

(6) The proportions of dairy farms in each area that are small farms or large farms will be the same as the average proportions for 1964, 1966.

(7) The annual change in the percentage of farms in Iowa that are specialized in the production of hogs and beef is equal to the observed historical trend in the percentage change that other specialized farms are of the total number of farms.

(8) The average size of a farm of type k in area i and of size j will be the same relative size to all types of farms in area i and of size j as it was on the average in 1964, 1966.

(9) All farmland in area i and size j not included in the specialized type (k=1, 2, 3, 4) of farms defined for that area - size category is land on general farms.

The estimated number and average size of each representative farm is shown in Table 65. The estimated total number of farms is very close to the total number of farms estimated by a linear time series projection to 1972 using 1950, 1954, 1959 and 1964 Census of Agriculture data. The time series estimate is 125,262 farms while the estimate derived in this study is 125,531. The total land in farms is 33,505,959 acres so the estimated average farm size for the state is 266.9 acres.

Table 65. Average size of the representative farms and the number of farms they represent

Representative farm number	Number of farms represented	Average size
		(acres)
1	9923	156.1
2	7831	155.8
3	6838	386.6
4	4827	464.3
5	5876	388.2
6	1796	144.5
7	6098	144.6
8	2445	405.0
9	2992	541.2
10	3492	391.9
11	2520	147.1
12	3597	116.7
13	8977	132.0
14	3612	435.5
15	9645	460.6
16	3036	136.0
17	4810	131.2
18	4365	151.5
19	10736	148.7
20	4688	424.2
21	7418	388.5
22	4212	150.4
23	1190	127.0
24	1485	163.6
25	1487	401.6
26	940	381.5
27	695	437.1

XI. APPENDIX B: MODEL CONSTRAINTS AND RESOURCE LEVELS

The data and methods used to estimate the resources on representative farms are presented in this Appendix. The resource quantities that needed to be estimated for each farm are operator and family labor by calendar periods, classes of land, livestock facilities, operating capital, and minimum income above variable costs.

A special feature of the model that also needs further explanation is the gross sales accounting row to maintain the farm type definitions.

An explanation of the methods used to estimate the aggregate resource levels of hired labor and feeder cattle for all of the farms was presented in Chapter IV. One additional constraint in the state portion of the model that is discussed in this Appendix is a limit on the quantity of feed grain that could be exported from the state.

A. Hours of Operator and Family Labor

Labor constraints were included in the model for total labor and for five calendar periods. In addition to dividing the operator and family labor into the amount available in each of these periods, a method was needed to account for the different quantities of labor found on farms on different sizes or different types. Then after the total hours of operator and family labor were estimated for each period on each representative farm, another calculation was made to subtract out hours of labor that would be needed for "overhead" activities on each farm. These overhead activities include repairs to machinery and equipment, repairs to buildings and improvements, fencing, management activities and general business trips to purchase supplies, attend meetings, etc.

Three sources of data were used to calculate the estimate of operator and family labor. Time series data on the number of operator and family workers for each month on all farms in the state is available in "Farm Labor", a monthly publication by the Statistical Reporting Service, U.S. Department of Agriculture. This data source also gives an estimate of average hours worked in one week of each month by all farm operators in the state.

To disaggregate the state labor data in "Farm Labor" to areas, sizes and types of farms, additional data from the 1964 and 1966 ERS Pesticide Use Surveys were used. This data source provided a cross sectional observation on labor use on each of the representative farms.

Trede (37) reported the percentage of labor used on farms each month that was used for overhead activities. He reported that 23.92 percent of total labor hours were devoted to overhead activities on the North Central Iowa hog farms he studied. Worden (47) reported that 23.22 percent of total labor hours were used for overhead activities on South Central Iowa farms with beef cow herds. This suggests that there is no difference between areas or types of farms in the percent of labor used for overhead. Trede's work also suggests that there is no difference between sizes of farms. He reported only a one percent difference in the percent of labor used for overhead activities on farms under 250 acres or over 250 acres.

The requirements for overhead labor shown in Table 66 are based on Trede's study and were used for all of the representative farms. The monthly and annual percentage figures reported by Trede have been adjusted downward by ten percent to allow for the overhead labor he reported was done by hired workers. Then Trede's figures for each month were decreased by another thirty-three percent to allow for flexibility in when overhead tasks can be done. The assumption is that two-thirds of the overhead work must be done in the month it was reported to be done while the other one-third can be done at some other time. The result of this assumption is that the sum of net operator and family labor available by periods will be greater than the net amount of operator and family labor available for the year.

The notation used to estimate the net hours of available operator and family labor by months on each representative farm is as follows:

subscripts: $i = 1, 2, \ldots, 27$ for the representative farms

$j = 1, 2, \ldots, 12$ for the months

$k = 1, 2$ for operators and family (1 = operator, 2 = family)

. = summed across the corresponding subscript

superscripts: none = data from "Farm Labor"

' = data from the 1964 and 1966 ERS Pesticide Use Surveys

* = data from Trede

" = other source of data

T = total

N = net

other: ^ = estimated for 1972, generally a time series projection when used on an exogenous variable.

The variables used are:

H = hours

$\hat{H}_{.j1}$ = hours worked in each month by a farm operator on all farms (time series projection to 1972 if a significant trend exists, otherwise the mean of 1965-69 data)

Table 66. Percent of operator and family labor needed for overhead activities

Month	Percent
January	19.36
February	16.46
March	17.57
April	17.64
May	14.58
June	16.76
July	12.01
August	27.29
September	24.55
October	14.69
November	9.24
December	16.86
Year	21.55

H'_{ij1} = hours worked in each month by a farm operator on each farm

$H'_{.j1}$ = hours worked in each month by a farm operator on all farms

H'_{ij2} = hours worked in each month by a family worker on each farm

N = number of workers

$\hat{N}_{.j.}$ = number of operator and family workers on all farms in each month

N''_{ij1} = number of farms represented by each representative farm (from Appendix A)

N'_{ij2} = number of family workers on each farm in each month

$N'_{.j2}$ = number of family workers on all farms in each month

P = proportion

$P^*_{.j.}$ = the proportion of operator and family labor needed for overhead activities in each month

The equations used are:

(W.1) $$N_{.j1} = \sum_{i=1}^{27} N''_{ij1}$$

(W.2) $$N_{.j2} = \hat{N}_{.j.} - N_{.j1}$$

(W.3) $$N_{ij2} = (N_{.j2}) \frac{N'_{ij2}}{N'_{.j2}}$$

(W.4) $H_{ij1} = (\hat{H}_{.j1}) \frac{H'_{iji}}{H'_{.j1}}$

(W.5) $H^T_{ij1} = (N_{ij1})(H_{ij1})$

(W.6) $H^T_{ij2} = (N_{ij2})(H'_{ij2})$

(W.7) $H^T_{ij.} = \sum_{k=1}^{2} H^T_{ijk}$

(W.8) $H^N_{ij.} = (H^T_{ij.})(1 - P^*_{.j.})$

The net hours of operator and family labor for each period were then derived by summing the appropriate months. The net hours for an individual farm can be calculated by dividing by the number of farms represented by each representative farm. This information is shwon in Table 67.

Several assumptions are implied when the method explained above is used to calculate the net hours of operator and family labor. These are:

(1) farm operators and family workers will not work more hours per month than they have been observed to work in recent years. Additional "available" hours are assumed to be needed for off farm work and other activities or not available at all because the operator will prefer to produce only those products that will not change his work load.

Table 67. Net hours of operator and family labor on each representative farm by periods

Representative farm number	Period: Dec-Mar	Apr-May	June-July	Aug-Sept	Oct-Nov	Total
1	285.7	372.0	363.7	294.7	393.4	1,623.6
2	627.0	565.8	673.6	501.8	544.9	2,774.9
3	434.0	473.2	486.2	379.4	532.0	2,187.6
4	701.3	529.3	514.7	431.6	524.4	2,571.6
5	719.3	625.7	743.3	545.6	653.6	3,126.9
6	527.4	398.9	348.4	299.0	396.7	1,873.1
7	558.9	423.1	396.2	330.7	424.3	2,028.8
8	454.9	455.2	423.4	334.2	497.9	2,052.7
9	674.7	439.9	396.7	321.2	449.3	2,167.9
10	708.1	498.1	485.7	388.9	504.2	2,457.6
11	410.5	414.8	364.2	317.3	356.6	1,774.2
12	550.2	383.9	373.8	304.8	375.2	1,892.2
13	549.1	449.7	454.3	351.5	407.0	2,104.9
14	549.1	557.5	553.9	412.0	532.5	2,474.8
15	764.9	632.6	687.5	494.2	620.3	3,040.8
16	329.0	351.8	355.4	250.2	417.0	1,610.2
17	794.2	556.9	537.8	455.6	550.8	2,755.7
18	742.2	493.1	482.0	399.6	505.8	2,495.2
19	683.6	522.5	525.2	417.0	531.1	2,547.5
20	547.3	511.6	436.9	307.4	514.7	2,194.0
21	871.6	638.1	670.3	512.1	666.4	3,191.9
22	761.9	483.1	487.4	423.9	508.7	2,537.3
23	712.8	468.5	452.1	383.3	461.0	2,358.2
24	634.6	588.3	656.0	490.9	585.3	2,810.5
25	881.2	526.1	548.9	468.4	556.4	2,839.0
26	785.8	608.8	608.7	480.6	628.4	2,957.5
27	697.6	620.8	677.1	514.4	643.8	2,997.6

(2) the observed historical trend in changes in the number of operator and family workers for each month will continue.

(3) the total number of family workers expected to be on all farms in 1972 will be distributed to farms in different areas, of different sizes and of different types, the same as they were on the average in 1964, 1966.

(4) there is only one operator on each farm.

(5) operators of farms in different areas, of different sizes and of different types will work as many hours relative to the average hours worked by all farm operators as they were observed to work on the average in 1964, 1966.

B. Acres of Land Resources

Six matrix rows were included in each farm sub-model to limit the use of land. Four of these rows have positive values in the resource vector depicting the limited amount of various classes of land. The other two rows are internal accounting rows to require consistency in land use.

1. Cropland and non-cropland pasture

The problem of estimating the acres of cropland and acres of non-cropland pasture for each representative farm is again a problem of inadequate data. The Census of Agriculture gives information on land use by size of farm or by type of farm only as state totals. The land use information by areas of the state is for all farms in the area.

The 1964 ERS Pesticide Use Survey contains information on total acres in each farm surveyed and acres in each crop except for acres diverted under the feed grain program. The 1966 ERS Pesticide Use Survey provides information on total acres in each farm and acres of cropland on each farm.

The general procedure followed to derive representative farm estimates of acres of cropland and non-cropland pasture from the pieces of data was:

(1) The acres of land reported in pasture in the 1964 ERS Pesticide Use Survey was sub-divided into cropland pasture and non-cropland pasture. This division was made by using data for each area from the 1964 Census of Agriculture. The percent of the land in each representative farm that was in non-cropland pasture was then calculated.

(2) The percent of the land in each representative farm that is cropland was calculated from the 1966 ERS Pesticide Use Survey.

(3) The land use percentages calculated in (1) and (2) above were adjusted or corrected to make their sum equal to the percent of land on all farms in

each area that was used for cropland and non-cropland pasture as reported in the 1964 Census of Agriculture.

(4) The acres of cropland and of non-cropland pasture were calculated for each representative farm starting from the base of total acres of land in each representative farm. The derivation of total acres for each representative farm is explained in Appendix A.

(5) The acres of cropland and of non-cropland pasture were adjusted to make the sum of each on all farms in an area equal to the total acres of cropland and of non-cropland pasture in each area according to Census of Agriculture data.

In notation form, the method of estimating acres of cropland and non-cropland pasture for each representative farm is:

subscripts: $i = 1,2,3,4,5$ for areas

j = representative farm within the area

$j = 1,2,3,4,5$ for $i = 1,2,3$

$j = 1,2,3,4,5,6$ for $i = 4,5$

$k = 1, 2$ for cropland and non-cropland pasture ($k = 1$ for cropland, $k = 2$ for non-cropland pasture)

. = summed across the corresponding subscript superscripts: none = data from the Census of Agriculture

' = data from the 1964 and 1966 ERS Pesticide Use Surveys

c = corrected

T = Total

* = final estimate of variable for 1971-1973

The variables are:

P = proportion

$P_{i.k}$ = proportion of land on all farms in an area that is cropland or non-cropland pasture

P'_{ijk} = proportion of land on each representative farm that is cropland or non-cropland pasture

A = acres

$A^T_{ij.}$ = total acres in each farm as estimated in Appendix A

$\sum_j A^T_{ij.}$ = sum of total acres in all farms in each area as estimated in Appendix A

The equations are:

$$(L.1) \quad P^{c'}_{ij.} = \frac{\sum_k P_{i.k}}{\sum_k P'_{ijk}}$$

$$(L.2) \quad P^{c'}_{ijk} = (P'_{ijk})(P^{c'}_{ij.})$$

$$(L.3) \quad A'_{ijk} = (A^T_{ij})(P^{C'}_{ijk})$$

$$(L.4) \quad A_{i.k} = (\sum_j A^T_{ij})(P_{i.k})$$

$$(L.5) \quad A^*_{ijk} = A'_{ijk} \frac{A_{i.k}}{\sum_j A'_{ijk}}$$

The estimates for acres of cropland and for acres of non-cropland pasture for each farm are shown in Table 68. The estimates of A^*_{ij1}, acres of cropland, are in the third column of the table while the acres of non-cropland pasture, A^*_{ij2} are in the sixth column of the table.

2. Row crop capability and corn base

Two additional land constraints defined for each farm are row crop capability and corn base. The first one limits the acres that can be planted to corn or soybeans or diverted under the feed grain program. The resource vector value for this constraint was calculated from unpublished data that had been used by Sharples to differentiate land classes (31, p. 27). This row crop capability for each farm is shown in Table 68.

The corn base constraint is needed for the Government feed grain program. If all farms participate in the program, the acres of corn plus diversion could not exceed the acres of corn base. Some corn base is also found and therefore

Table 68. Acres of land resources on each representative farm

Representative farm number	Total	Cropland	Row Crop capability	Corn base	Non-cropland pasture
1	156.1	141.0	128.6	79.5	5.4
2	155.8	136.5	124.5	76.9	9.4
3	386.6	347.8	317.3	196.1	14.6
4	464.3	342.2	312.2	192.9	88.4
5	388.2	346.6	316.2	195.4	17.2
6	144.5	120.8	83.4	65.0	11.8
7	144.6	119.1	82.2	64.1	13.7
8	405.0	340.2	234.8	183.1	31.5
9	541.2	430.4	296.9	231.6	66.4
10	391.9	320.7	221.3	172.5	39.1
11	147.1	112.9	70.2	48.2	13.5
12	116.7	77.3	48.1	33.0	28.5
13	132.0	85.7	53.3	36.6	34.9
14	435.5	298.6	185.6	127.5	92.0
15	460.6	292.8	181.9	125.0	131.0
16	136.0	114.4	102.3	60.8	11.1
17	131.2	104.2	93.1	55.4	18.3
18	151.5	123.1	110.1	65.4	17.7
19	148.7	121.2	108.3	64.4	17.0
20	424.2	358.8	320.8	190.7	32.1
21	388.5	313.4	280.2	166.6	48.2
22	150.4	92.0	49.2	38.5	56.7
23	127.0	87.0	46.6	36.4	22.6
24	163.6	107.3	57.5	44.9	42.1
25	401.6	280.0	150.1	117.2	58.0
26	381.5	272.0	145.8	113.8	38.7
27	437.1	272.4	146.1	114.0	150.9

"used" on farms that don't participate in the program. It is assumed that for the state average no farm will produce more than 1.54 acres of corn for each acre of corn base--that each acre of non-participating corn will require .65 of an acre of corn base. By areas the requirement ranged from .59 to .72 of an acre of corn base for each acre of non-participating corn.

The acres of corn base for each area of the state is summed from county data published by the Agriculture Stabilization and Conservation Service, U.S. Department of Agriculture. The percent of cropland in the area that is corn base was calculated for each area and this percentage was assumed to apply to all sizes and types of farms in the area. The acreage of corn base on each farm is shown in column five of Table 68.

3. Conservation base and nurse crop accounting rows

One requirement for participating in the Government feed grain program is to maintain a part of an acre in an approved conservation practice for each acre of corn base enrolled in the program. For an individual farm with, for example, a 100 acre corn base this would be a unique minimum acreage requirement of, say, 22 acres. For an aggregate of farms with this same ratio of conservation base to corn base this relationship can be expressed as .22 acres of conservation base required for each one acre of corn base enrolled in the feed grain program.

Data provided by the Agriculture Stabilization and Conservation Service, U.S. Department of Agriculture, shows that farms in area 1 must have .072 of an acre of conservation base for each acre of corn enrolled in the feed grain program. For the other areas, this figure ranges upward to .703 of an acre in area 5. This internal consistency requirement was forced into the model solutions by requiring, for example, .703 of an acre of rotation meadow for each acre of corn base enrolled in the feed grain program in area 5.

The nurse crop accounting row is also used to maintain internal consistency in the model. For each acre of rotation meadow included in the solution some portion of an acre of oats or feed grain diversion is required to be included in the solution as a nurse crop. This requirement ranged from .40 of an acre in area 5 to .55 of an acre in area 1.

C. Operating Capital

The resource vector vector value for operating capital is defined as the amount of operating capital in the possession of the farm operator plus the amount be can borrow. To estimate this value, data from the 1964 and 1966 ERS Pesticide Use Surveys were processed to determine the farm operator's equity in liquid production assets on each representative farm. An annual increase of four percent in this equity was assumed--equal to the annual increase in equity in liquid production assets on all farms in the U.S. in the past five years. The result was an estimate of $1.32 of equity in liquid production assets for each $1.00 of equity found on the surveyed farms in 1964 and 1966.

Two additional assumptions were used to derive the resource vector values for operating capital. These were:

(1) one-fourth of the estimate of operator's equity in liquid production assets would be available to pay variable costs of production. The remaining portion is invested in other production assets.

(2) the operator can borrow capital to pay variable production expenses and the maximum amount he can borrow is equal to one-fourth of the amount of his equity in liquid production assets.

The estimates of operating capital resources for each farm are listed in Table 69. The estimates range from about $9000 to over $40,000. If property is purchased that can be mortgaged, this resource vector value for operating capital is increased. For example, buying feeder cattle adds ninety percent of their purchase price to the operating capital limit.

Table 69. Available operating capital resource on each representative farm

Representative farm number	Capital
	(Dollars)
1	9,006
2	13,537
3	20,613
4	30,875
5	24,455
6	16,989
7	14,813
8	12,118
9	40,229
10	18,468
11	9,251
12	10,385
13	11,806
14	16,984
15	23,739
16	14,329
17	12,068
18	15,673
19	13,338
20	18,264
21	21,303
22	11,379
23	16,105
24	15,670
25	21,070
26	37,696
27	25,889

D. Livestock Facilities

Two equations were included in each farm sub-model to limit hog farrowing capacity. One equation limits the number of sows that can be farrowed the first and third quarter of the year while the other limits farrowing capacity in the second and fourth quarters.

Data on hog farrowing capacity on farms was not available so an estimate was made using hog sales data from the 1964 and 1966 ERS Pesticide Use Surveys. First, the total number of litters sold from each representative farm in 1964 and 1966 was estimated. Then the number of spring litters was estimated as fifty-six percent of all litters farrowed since this is the approximate historical percentage of all litters that are farrowed in the spring. Finally, the estimated number of spring litters was divided by 1.2 to account for the multiple use of farrowing facilities on some farms. The estimated farrowing capacity for each quarter of the year is shown in Table 70. Additional farrowing capacity could be purchased on each farm.

The dairy cow space was limited on each of the three dairy farms. This estimated resource value was obtained from data on dairy cow facilities in the 1964 ERS Pesticide Use Survey. The dairy cow capacity for the three dairy farms is shown in Table 70. Additional facilities could be purchased on each farm.

Table 70. Hog farrowing and dairy cow facilities on each representative farm

Representative farm number	Quarterly farrowing capacity	Dairy capacity
	(litters)	(cows)
1	2.0	
2	13.0	
3	5.0	
4	14.0	
5	21.0	
6	5.0	
7	9.0	
8	4.0	
9	6.0	
10	21.0	
11	2.0	
12	22.0	
13	5.0	
14	4.0	
15	14.0	
16	3.0	
17	3.0	23.0
18	34.0	
19	7.0	
20	4.0	
21	10.0	
22	3.0	21.0
23	24.0	
24	9.0	
25	11.0	23.0
26	20.0	
27	18.0	

E. Minimum Returns over Variable Costs

The relevant costs for a producer to consider when choosing which products to include in his operation are the variable costs. These variable costs are included in the budgets for the activities in the model.

For the producer to stay in operation over some period of time he must also have sufficient returns to cover certain other costs that don't enter into the choice of products to produce. These fixed costs include family living; depreciation, taxes, insurance, and interest on investment for machinery and equipment; depreciation and insurance for buildings and improvements; and real estate taxes.

An equation was included in each farm sub-model to require the returns over the variable costs of production to be large enough to pay these fixed costs or no production would take place. The fixed costs that were included in this minimum income constraint are:

(1) $3000 for family living. This is a bare minimum for family living costs but data from the 1964 Census of Agriculture shows that an average of $2600 per farm was received as non-farm income.

(2) Twenty percent of the value of machinery and equipment on each farm. This is for depreciation, taxes, insurance and interest on investment for the

machinery and equipment.

(3) An estimated value for depreciation and insurance for buildings and improvements.

(4) An estimated cost for real estate taxes. The real estate taxes for 1972 were estimated to range from $4.12 per acre in area 3 to $5.89 per acre in areas 1 and 4.

Table 71 shows the sum of these four quantities for each farm. This quantity multiplied by the number of farms represented by each representative farm gives the resource vector value for the minimum income equations in the model.

F. Gross Sales Accounting

One of the features included in the model is to require that cash grain farms, dairy farms, hog farms and beef farms produce a mixture of products that will maintain their type classification. Since the type classifications are based on gross sales data this feature is handled with a gross sales accounting equation in each of the farm sub-models for specialized farms.

The criteria for each specialized type of farm is:

(1) Cash grain - two thirds or more of the total sales must be from crops produced on the farm. The definition used to select cash grain farms was that at least one-half of the gross sales must be from

Table 71. Minimum income above variable costs required on each representative farm

Representative farm number	Minimum income
	(Dollars)
1	6,016
2	6,228
3	9,503
4	10,852
5	9,755
6	6,267
7	5,983
8	8,306
9	10,881
10	8,431
11	5,991
12	5,305
13	5,469
14	8,653
15	8,905
16	7,296
17	5,862
18	6,322
19	6,227
20	9,963
21	8,977
22	5,789
23	5,736
24	6,215
25	8,677
26	10,127
27	9,082

crops. However, data from the 1964 Census of Agriculture and from the 1964 and 1966 ERS Pesticide Use Surveys show that the average cash grain farm in Iowa receives at least two-thirds of its gross sales from crops. Thus the two-thirds criteria was used to maintain the cash grain type classification.

(2) Dairy - one-half or more of the gross sales must be from dairy products or animals.

(3) Hog - seventy percent or more of the gross sales must be pork.

(4) Beef - seventy percent or more of the gross sales must be beef.

The gross sales accounting equation accumulates the gross sales information from each product sold from a farm and limits the sales to those products that will maintain the type classification. For the four types of specialized farms the equations are:

(1) cash grain farms

$$P + B + D - .5C \leq 0$$

(2) dairy farms

$$C + P + B - D \leq 0$$

(3) hog farms

$$C + B + D - .43\ P \leq 0$$

(4) beef farms

$$C + P + D - .43\ B \leq 0$$

where C = gross sales from crops

P = gross sales from pork

B = gross sales from beef

D = gross sales from dairy

These equations used in the model are derived from equations that express the type definition. For example, the cash grain farm must have gross sales from crops that is greater than or equal to two-thirds of its total gross sales.

$$.667(C + P + B + D) \leq C$$

Manipulation of this equation gives us the equation to be used in the model.

$$.667C + .667P + .667B + .667D \leq C$$

$$.667P + .667B + 667D \leq .333C$$

$$.667P + .667B + .667D - .333C \leq 0$$

$$P + B + D - .5C \leq 0$$

G. Maximum Quantity of Feed Grains Shipped Out of the State

Rather than assume a perfectly elastic demand for feed grains by the other forty-nine states, a limit was placed on the amount of feed grains that could be shipped out of Iowa. The defined maximum quantity also considered the demand for feed grains by other livestock produced in Iowa but not included in the model. The numerical limit was defined as 120 percent of the surplus feed grain production in Iowa on the average from 1964 to 1968 plus an estimated quantity of feed grains used by poultry, sheep and horses in Iowa. The resource vector value used was 440,000,000 bushels.

XII. APPENDIX C: MODEL ACTIVITIES, TECHNICAL COEFFICIENTS AND PRICES

The budgets for the production activities on each representative farm reflect expected average management practices for 1971-1973, the years the model represents. Crop inputs that are changing from year to year such as the use of fertilizer and chemicals were projected from time series data or estimated by extension specialists. The continuing shift to larger tractors and equipment was taken into consideration in calculating power and machine costs and in estimating labor requirements. Crop yields were projected to 1972 as were crop drying costs, use of commercial storage, the trend toward harvesting more corn with combines, and increasing use of seed to get higher plant populations in corn.

The budgets for the crop activities vary by different areas and size of farms. The crop yields, the difficulty of tilling different soil types, and the general topography of the land make the budgets different for each area. The size of power units and other equipment, the percent of the tractors that are diesel powered, and the amount of custom machine hire make the budgets different for the small and large farms.

The livestock budgets are based on an assumed size of enterprise as shown in Table 72. Sales data from the 1964

Table 72. Size of enterprise assumptions for livestock budgets

Type of livestock	Size assumptions	Unit	Quantity
Dairy	-	Cow	25-30
Beef cow herd	Small	Cow	10-15
	Medium	Cow	30-40
	Large	Cow	60-75
Beef feeders	Small	Head	25-30
	Medium	Head	70-85
	Large	Head	200-250
Hogs	Small	Litter	10-15
	Medium	Litter	30-35
	Large	Litter	60-70

and 1966 ERS Pesticide Use Surveys were used to determine what size of enterprise to assume for each livestock activity on each representative farm. The specialized beef and hog farms are assumed to have more mechanized livestock facilities and also to be more skilled in the management of these enterprises. This is reflected in a higher percent calf crop for beef cow herds, in more pigs per litter and in improved feed efficiency for hog activities, and in lower labor requirements for all specialized enterprises.

Tables 73-88 give the budget data in summary form. The variable costs that are included in the crop budgets when applicable are:

(1) seed

(2) fuel, lubrication and repairs for tractors

Table 73. Representative farm budgets for corn for grain

	Representative farm number									
	1,2	3,4 5	6,7	8,9 10	11,12 13	14,15	16,17 18,19	20,21	22,23 24	25,26 27
Yield (bushel)	104.00	104.00	101.00	101.00	99.00	99.00	107.00	107.00	100.00	100.00
Preharvest:										
Seed	$4.16	$4.16	$3.84	$3.84	$3.84	$3.84	$4.64	$4.64	$4.16	$4.16
Tractor & equip.	$3.59	$3.03	$3.70	$3.12	$3.80	$3.21	$3.59	$3.03	$3.95	$3.33
Fertilizer:										
Lbs. of N	139.00	139.00	135.00	135.00	122.00	122.00	131.00	131.00	117.00	117.00
Lbs. of P	36.00	36.00	33.00	33.00	29.00	29.00	34.00	34.00	31.00	31.00
Lbs. of K	48.00	48.00	42.00	42.00	33.00	33.00	46.00	46.00	49.00	49.00
Chemicals	$5.84	$5.84	$5.70	$5.70	$5.02	$5.02	$5.70	$5.70	$5.20	$5.20
Total pre-harvest cost	$35.13	$34.55	$33.14	$32.54	$30.88	$30.26	$34.84	$34.26	$32.36	$31.72
Harvest:										
Tractor & equip.	$1.65	$1.65	$1.70	$1.70	$1.76	$1.76	$1.65	$1.65	$1.81	$1.81
Custom hire	$2.74	$2.19	$2.70	$2.16	$3.01	$2.38	$2.86	$2.29	$2.76	$2.21
Drying & storage	$3.95	$3.95	$3.05	$3.05	$4.18	$4.18	$4.08	$4.08	$3.91	$3.91
Total harvest cost	$8.34	$7.79	$7.45	$6.91	$8.95	$8.32	$8.59	$8.02	$8.48	$7.93
TOTAL VARIABLE COST	$43.47	$42.34	$40.59	$39.45	$39.83	$38.58	$43.43	$42.28	$40.84	$39.65
Labor[a] (hrs/acre)	5.06	4.44	5.40	4.76	5.56	4.88	5.06	4.44	5.72	5.02

[a]Total hours of labor were allocated to periods as follows: 4.2%, Dec.-Mar.; 25.1%, Apr.-May; 14.1%, June-July; 6.4%, Aug.-Sept.; 50.0%, Oct.-Nov.

Table 74. Representative farm budgets for corn silage

	Representative farm number									
	1,2	3,4 5	6,7	8,9 10	11,12 13	14,15	16,17 18,19	20,21	22,23 24	25,26 27
Yield (ton)	16.00	16.00	16.00	16.00	15.00	15.00	17.00	17.00	16.00	16.00
Preharvest:										
Seed	$4.16	$4.16	$3.84	$3.84	$3.84	$3.84	$4.64	$4.64	$4.16	$4.16
Tractor & equip.	$3.61	$3.03	$3.71	$3.12	$3.82	$3.22	$3.61	$3.03	$3.97	$3.34
Fertilizer:										
Lbs. of N	139.00	146.00	135.00	135.00	122.00	122.00	131.00	131.00	117.00	117.00
Lbs. of P	35.00	37.00	33.00	33.00	29.00	29.00	34.00	34.00	31.00	31.00
Lbs. of K	48.00	48.00	42.00	42.00	33.00	33.00	46.00	46.00	49.00	49.00
Chemicals	$5.84	$5.84	$5.70	$5.70	$5.02	$5.02	$5.70	$5.70	$5.20	$5.20
Total pre-harvest cost	$35.63	$35.03	$32.94	$32.33	$30.70	$30.08	$34.53	$33.93	$32.18	$31.52
Harvest:										
Tractor & equip.	$5.06	$5.06	$5.21	$5.36	$5.36	$5.36	$5.06	$5.06	$5.57	$5.57
Custom hire	$9.08	$6.05	$8.84	$5.89	$8.66	$5.78	$9.32	$6.21	$8.78	$5.85
Total harvest cost	$14.14	$11.11	$14.05	$11.25	$14.02	$11.14	$14.38	$11.27	$14.35	$11.42
TOTAL VARIABLE COST	$49.77	$46.14	$46.99	$43.58	$44.72	$41.22	$48.91	$45.20	$46.53	$42.94
Labor[a] (hrs/acre)	10.07	9.45	10.37	9.73	10.67	10.02	10.07	8.06	11.08	10.40

[a]Total hours of labor were allocated to periods as follows: 5.0%, Oct.-Nov.; same actual hours as corn for grain, Dec.-Mar., Apr.-May, June-July; balance of hours, Aug.-Sept.

Table 75. Representative farm budgets for oats

	Representative farm number									
	1,2	3,4 5	6,7	8,9 10	11,12 13	14,15	16,17 18,19	20,21	22,23 24	25,26 27
Yield (Bushels)	76.00	76.00	60.00	60.00	57.00	57.00	70.00	70.00	70.00	70.00
Preharvest:										
Seed	$2.40	$2.40	$2.40	$2.40	$2.40	$2.40	$2.40	$2.40	$2.40	$2.40
Tractor & equip.	$.92	$.78	$.95	$.81	$.97	$.82	$.92	$.78	$1.02	$.86
Fertilizer:										
Lbs. of N	7.00	7.00	6.00	6.00	5.00	5.00	3.00	3.00	3.00	3.00
Lbs. of P	11.00	11.00	12.00	12.00	10.00	10.00	7.00	7.00	4.00	4.00
Lbs. of K	3.00	3.00	5.00	5.00	7.00	7.00	4.00	4.00	1.00	1.00
Total pre-harvest cost	$7.39	$7.24	$7.63	$7.48	$7.71	$7.55	$6.53	$6.39	$5.68	$5.52
Harvest:										
Tractor & equip.	$1.16	$1.16	$1.19	$1.19	$1.23	$1.23	$1.16	$1.16	$1.28	$1.28
Custom hire	$2.10	$1.62	$2.10	$1.62	$2.10	$1.62	$2.10	$1.62	$2.10	$1.62
Total harvest cost	$3.26	$2.78	$3.29	$2.81	$3.33	$2.85	$3.26	$2.78	$3.38	$2.90
TOTAL VARIABLE COST	$10.65	$10.02	$10.92	$10.29	$11.04	$10.40	$9.79	$9.17	$9.06	$8.42
Labor[a] (hrs/acre)	2.06	1.84	2.20	1.97	2.27	2.02	2.06	1.84	2.33	2.08

[a]Total hours of labor were allocated to periods as follows: 13.0% Dec.-Mar.; 7.5% Apr.-May; 70.0% June-July; 8.5% Aug.-Sept.; 1.0% Oct.-Nov.

Table 76. Representative farm budgets for soybeans

	Representative farm number									
	1,2	3,4 5	6,7	8,9 10	11,12 13	14,15	16,17 18,19	20,21	22,23 24	25,26 27
Yield (Bushels)	33.00	33.00	33.00	33.00	32.00	32.00	32.00	32.00	31.00	31.00
Preharvest:										
Seed	$3.74	$3.74	$3.41	$3.41	$3.41	$3.41	$3.74	$3.74	$3.41	$3.41
Tractor & equip.	$3.54	$2.97	$3.64	$3.06	$3.75	$3.14	$3.54	$2.97	$3.90	$3.26
Fertilizer:										
Lbs. of N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lbs. of P	2.00	2.00	2.00	2.00	1.00	1.00	1.00	1.00	4.00	4.00
Lbs. of K	3.00	3.00	1.00	1.00	1.00	1.00	0.00	0.00	6.00	6.00
Chemicals	$5.69	$5.69	$6.06	$6.06	$6.43	$6.43	$6.59	$6.59	$6.66	$6.66
Total pre-harvest cost	$15.13	$14.54	$14.99	$14.38	$15.58	$14.94	$15.81	$15.22	$16.82	$16.15
Harvest:										
Tractor & equip.	$.92	$.92	$.95	$.95	$.98	$.98	$.92	$.92	$1.01	$1.01
Custom hire	$3.00	$2.48	$3.00	$2.48	$2.98	$2.46	$2.98	$2.46	$2.97	$2.45
Total harvest cost	$4.54	$4.02	$4.45	$3.93	$4.44	$3.92	$4.50	$3.98	$4.33	$3.81
TOTAL VARIABLE COST	$19.67	$18.56	$19.44	$18.31	$20.02	$18.86	$20.32	$19.20	$21.15	$19.96
Labor[a] (hrs/acre)	3.57	3.01	3.82	3.22	3.93	3.31	3.57	3.01	4.03	3.40

[a]Total hours of labor were allocated to periods as follows: For farms 6-15; 2.0% Dec.-Mar.; 25.2% Apr.-May; 38.0% June-July; 18.0% Aug.-Sept.; 16.8% Oct.-Nov.; for all other farms: 2.0% Dec-Mar.; 25.2% Apr.-May; 38.0% June-July; 11.8% Aug.-Sept.; 23.0% Oct.-Nov.

Table 77. Representative farm budgets for hay

	Representative farm number									
	1,2	3,4 5	6,7	8,9 10	11,12 13	14,15	16,17 18,19	20,21	22,23 24	25,26 27
Yield (Ton)	3.23	3.23	3.08	3.08	2.70	2.70	3.03	3.03	3.25	3.25
Preharvest:										
Seed	$3.40	$3.40	$3.00	$3.00	$2.70	$2.70	$3.10	$3.10	$2.40	$2.40
Tractor & equip.	$.50	$.42	$.51	$.43	$.54	$.45	$.50	$.42	$.55	$.48
Fertilizer:										
Lbs. of N	8.00	8.00	3.00	3.00	3.00	3.00	2.00	2.00	1.00	1.00
Lbs. of P	15.00	15.00	14.00	14.00	9.00	9.00	6.00	6.00	3.00	3.00
Lbs. of K	24.00	24.00	6.00	6.00	23.00	23.00	13.00	13.00	4.00	4.00
Total pre-harvest cost	$10.37	$10.28	$8.21	$8.12	$8.45	$8.06	$7.04	$6.95	$4.97	$4.87
Harvest:										
Tractor & equip.	$4.63	$4.45	$4.57	$4.37	$4.32	$4.10	$4.47	$4.28	$4.65	$4.64
Custom hire	$6.20	$5.43	$5.91	$5.17	$5.18	$4.54	$5.82	$5.09	$6.24	$5.46
Total harvest cost	$12.38	$11.56	$11.96	$11.14	$10.80	$10.04	$11.74	$10.95	$12.45	$11.79
TOTAL VARIABLE COST	$22.75	$21.84	$20.17	$19.26	$18.95	$18.10	$18.78	$17.90	$17.42	$16.66
Labor[a] (hrs/acre)	7.74	7.20	7.59	7.03	6.80	6.29	7.28	6.78	8.17	7.56

[a]Total hours of labor were allocated to periods as follows: 5.3% Apr.-May; 59.7% June-July; 35.0% Aug.-Sept.

Table 78. Representative farm budgets for diverted acres

	Representative farm number									
	1,2	3,4 5	6,7	8,9 10	11,12 13	14,15	16,17 18,19	20,21	22,23 24	25,26 27
Seed	$.65	$.65	$.65	$.65	$.65	$.65	$.65	$.65	$.65	$.65
Tractor & equip.	$1.22	$1.03	$1.25	$1.06	$1.29	$1.09	$1.22	$1.03	$1.34	$1.13
TOTAL VARIABLE COST	$2.08	$1.89	$2.13	$1.94	$2.70	$2.50	$2.53	$2.34	$2.62	$2.41
Labor[a] (hrs/acre)	1.20	.96	1.28	1.03	1.32	1.06	1.20	.96	1.36	1.08

[a]Total hours of labor were allocated to periods as follows: 50% April-May; 50% June-July.

Table 79. Representative farm budget for dairy cows

	Representative farm number 17, 22, 25
Production:	
Milk (lbs.)	9,000.00
Cull cow (Cwt.)	2.20
Veal calf (head)	.70
Variable cost:	
Protein supplement	$29.15
Vet. and drugs	$12.92
Taxes	$5.00
Breeding	$9.60
Power and equipment	$21.00
TOTAL VARIABLE COST	$77.67
Interest on investment	$33.92
Corn (bu.)	56.80
Hay (ton)	5.30
Pasture (acres of non-cropland pasture equiv.)	3.20
Labor (hrs./head)	
Total	75.00
Dec.-Mar.	30.00
Apr.-May	13.50
June-July	9.00
Aug.-Sept.	9.75
Oct.-Nov.	12.75

Table 80. Representative farm budgets for beef cows

	Representative farm number							
	2,18,19 23,24	5,21, 27	7,8,11, 12,14	10,13	15	4,26	6	9
Production:								
Cull cow (cwt)	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76
Calf (head)	.72	.72	.72	.72	.72	.76	.76	.76
Variable cost:								
Protein supplement	$2.75	$2.75	$2.20	$2.20	$2.20	$2.75	$2.20	$2.20
Vet. and drugs	$3.15	$3.15	$3.15	$3.15	$3.15	$3.15	$3.15	$3.15
Taxes	$4.20	$4.20	$4.20	$4.20	$4.20	$4.20	$4.20	$4.20
Breeding	$3.50	$3.50	$3.50	$3.50	$3.50	$3.50	$3.50	$3.50
Marketing	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00
TOTAL VARIABLE COST	$18.60	$18.60	$18.05	$18.05	$18.05	$18.60	$18.05	$18.05
Interest on investment	$24.71	$24.71	$24.69	$24.69	$24.69	$24.71	$24.69	$24.69
Corn (bu)	3.30	3.30	2.70	2.70	2.70	3.30	2.70	2.70
Hay (ton)	1.96	1.96	1.62	1.62	1.62	1.96	1.62	1.62
Pasture (acres of non-cropland pasture equivalent)	3.27	3.27	3.82	3.82	3.82	3.27	3.82	3.82
Labor[a] (hrs.cow)	17.32	11.55	14.18	9.45	5.67	6.27	8.55	5.13

[a]Total hours of labor were allocated to periods as follows: 45% Dec.-Mar.; 20% Apr.-May; 11% June-July; 12% Aug.-Sept; 12% Oct.-Nov.

Table 81. Representative farm budgets for small, non-specialized beef feeding enterprises[a]

	Calves, not pastured	Calves, pastured	Fall purchased yearlings	Spring purchased yearlings, not pastured	Spring purchased yearlings, pastured
Production:					
Selling weight (cwt)	10.46	10.46	10.73	10.73	10.73
Purchase weight (cwt)	4.68	4.68	6.39	6.39	6.39
Net gain (cwt)	5.78	5.78	4.34	4.34	4.34
Variable cost:					
Protein supplement	$12.50	$11.50	$9.00	$9.00	$6.00
Vet. and drugs	$2.10	$2.10	$1.10	$1.10	$1.10
Taxes	0.00	0.00	$2.00	0.00	0.00
Power and equipment	$3.50	$3.50	$2.50	$2.50	$2.50
Purchase expense	3.00	3.00	$3.25	$3.25	$3.25
Marketing expense	$5.00	$5.00	$5.00	$5.00	$5.00
TOTAL VARIABLE COST	$26.10	$25.10	$22.85	$20.85	$17.85
Corn (bu)	60.00	58.00	45.00	45.00	45.00
Hay (ton)	.85	.75	.83	.83	.47
Pasture (acres of non-cropland pasture equivalent)	0.00	.34	0.00	0.00	.82
Labor (hrs./head):					
Total	14.40	11.52	9.6	9.6	7.68
Dec.-Mar.	5.18	4.15	5.18	0.00	0.00
Apr.-May	2.53	2.03	1.94	3.21	2.56
June-July	1.87	1.50	1.92	3.03	2.43
Aug.-Sept.	2.51	2.00	0.00	3.36	2.69
Oct.-Nov.	2.30	1.84	.56	0.00	0.00

[a]These beef feeding budgets were used on representative farms 1,3,7,8,12,13,14, 16,18,19,20,23,24, and 25.

Table 82. Representative farm budgets for medium, non-specialized beef feeding enterprises[a]

	Calves not pastured	Calves, pastured	Fall purchased yearlings	Spring purchased yearlings, not pastured	Spring purchased yearlings, pastured
Production:					
Selling weight (cwt)	10.46	10.46	10.73	10.73	10.73
Purchase weight (cwt)	4.68	4.68	6.39	6.39	6.39
Net gain (cwt)	5.78	5.78	4.34	4.34	4.34
Variable cost:					
Protein supplement	$12.50	$11.50	$9.00	$9.00	$6.00
Vet. and drugs	$2.10	$2.10	$1.10	$1.10	$1.10
Taxes	0.00	0.00	$2.00	0.00	0.00
Power and equipment	$3.50	$3.50	$2.50	$2.50	$2.50
Purchase expense	3.00	3.00	$3.25	$3.25	$3.25
Marketing expense	$5.00	$5.00	$5.00	$5.00	$5.00
TOTAL VARIABLE COST	$26.10	$25.10	$22.85	$20.85	$18.15
Corn (bu)	60.00	58.00	45.00	45.00	45.00
Hay (ton)	.85	.75	.83	.83	.47
Pasture (acres of non-cropland pasture equivalent)	0.00	.34	0.00	0.00	.82
Labor (hrs/head):					
Total	9.60	7.68	7.20	7.20	5.76
Dec.-Mar.	3.46	2.76	3.89	0.00	0.00
Apr.-May	1.69	1.35	1.45	2.40	1.92
June-July	1.25	1.00	1.44	2.28	1.82
Aug.-Sept.	1.67	1.34	0.00	2.52	2.02
Oct.-Nov.	1.54	1.23	.42	0.00	0.00

[a]These beef feeding budgets were used on representative farms 2,5,10,15,21 and 27.

Table 83. Representative farm budgets for medium, specialized beef feeding enterprises[a]

	Calves, not pastured	Calves, pastured	Fall purchased yearlings	Spring purchased yearlings, not pastured	Spring purchased yearlings, pastured
Production:					
Selling weight (cwt)	10.46	10.46	10.73	10.73	10.73
Purchase weight (cwt)	4.68	4.68	6.39	6.39	6.39
Net gain (cwt)	5.78	5.78	4.34	4.34	4.34
Variable cost:					
Protein supplement	$12.50	$11.50	$9.00	$9.00	$6.00
Vet. and drugs	$2.10	$2.10	$1.10	$1.10	$1.10
Taxes	0.00	0.00	$2.00	0.00	0.00
Power and equipment	$3.50	$3.50	$2.50	$2.50	$2.50
Purchase expense	$3.00	$3.00	$3.25	$3.25	$3.25
Marketing expense	$5.00	$5.00	$5.00	$5.00	$5.00
TOTAL VARIABLE COST	$26.10	$25.10	$22.85	$20.85	$17.85
Corn (bu)	60.00	58.00	45.00	45.00	45.00
Hay (ton)	.85	.75	.83	.83	.47
Pasture (acres of non-cropland pasture equivalent)	0.00	.34	0.00	0.00	.82
Labor (hrs./head):					
Total	4.80	3.84	3.60	3.60	2.88
Dec.-Mar.	1.73	1.38	1.94	.00	0.00
Apr.-May	.84	.68	.73	1.20	.96
June-July	.62	.50	.72	1.14	.91
Aug.-Sept.	.84	.67	.00	1.26	1.01
Oct.-Nov.	.77	.61	.21	.00	.00

[a]These beef feeding budgets were used on representative farm 6.

Table 84. Representative farm budgets for large, specialized beef feeding enterprises[a]

	Calves, not pastured	Calves, pastured	Fall purchased yearlings	Spring purchased yearlings, not pastured	Spring purchased yearlings, pastured
Production:					
Selling weight (cwt)	10.46	10.46	10.73	10.73	10.73
Purchase weight (cwt)	4.68	4.68	6.39	6.39	6.39
Net gain (cwt)	5.78	5.78	4.34	4.34	4.34
Variable cost:					
Protein supplement	$12.50	$11.50	$9.00	$9.00	$6.00
Vet. and drugs	$2.10	$2.10	$1.10	$1.10	$1.10
Taxes	0.00	0.00	$2.00	0.00	0.00
Power and equipment	$3.50	$3.50	$2.50	$2.50	$2.50
Purchase expense	$3.00	$3.00	$3.25	$3.25	$3.25
Marketing expense	$5.00	$5.00	$5.00	$5.00	$5.00
TOTAL VARIABLE COST	$26.10	$25.10	$22.85	$20.85	$17.85
Corn (bu)	60.00	58.00	45.00	45.00	45.00
Hay (ton)	.85	.75	.83	.83	.47
Pasture (acres of non-cropland pasture equivalent)	0.00	.34	0.00	0.00	.82
Labor (hrs./head):					
Total	3.60	2.88	2.40	2.40	1.92
Dec.-Mar.	1.30	1.04	1.30	.00	.00
Apr.-May	.63	.51	.48	.80	.64
June-July	.47	.37	.48	.76	.61
Aug.-Sept.	.63	.50	.00	.84	.67
Oct.-Nov.	.58	.46	.14	.00	.00

[a]These beef feeding budgets were used on representative farms 4, 9, and 26.

Table 85. Representative farm budgets for small, non-specialized hog enterprises[a]

	Two litter, Feb. & Aug. farrow	Two litter, May & Nov. farrow	One litter, June farrow
Production:			
Sow (cwt)	4.50	4.50	4.50
Butchers (cwt)	30.82	30.82	14.26
Variable cost:			
Protein supplement	$115.00	$115.00	$59.80
Vet. and drugs	$18.48	$18.48	$9.24
Breeding	$3.00	$3.00	$1.50
Power and equipment	$11.50	$11.50	$6.75
Custom trucking	$6.00	$6.00	$3.00
TOTAL VARIABLE COST	$153.98	$153.98	$80.29
Interest on investment	$12.72	$12.72	$9.89
Corn (bu)	200.00	200.00	104.00
Labor (hrs/unit of activity)			
Total	50.00	50.00	25.00
Dec.-Mar.	17.50	14.50	.90
Apr.-May	7.50	11.00	1.80
June-July	8.00	7.50	11.10
Aug.-Sept.	10.50	7.50	6.50
Oct.-Nov.	6.50	9.50	4.60

[a]These hog budgets were used on representative farms 1,3, 6,8,9,11,16,17,20, and 22.

Table 86. Representative farm budgets for medium, non-specialized hog enterprises[a]

	Two litter, Feb. & Aug. farrow	Two litter, May & Nov. farrow	One litter, June farrow
Production:			
Sow (cwt)	4.50	4.50	4.50
Butchers (cwt)	30.82	30.82	14.26
Variable cost:			
Protein supplement	$115.00	$115.00	$59.80
Vet. and drugs	$18.48	$18.48	$9.24
Breeding	$3.00	$3.00	$1.50
Power and equipment	$11.50	$11.50	$6.75
Custom trucking	$6.00	$6.00	$3.00
TOTAL VARIABLE COST	$153.98	$153.98	$80.29
Interest on investment	$12.72	$12.72	$9.89
Corn (bu)	200.00	200.00	104.00
Labor (hrs/unit of activity)			
Total	40.00	40.00	20.00
Dec.-Mar.	14.00	11.60	.70
Apr.-May	6.00	8.80	1.50
June-July	6.40	6.00	8.90
Aug.-Sept.	8.40	6.00	5.20
Oct.-Nov.	5.20	7.60	3.70

[a]These hog budgets were used on representative farms 2,4, 7,13,14,19,21,24, and 25.

Table 87. Representative farm budgets for large, non-specialized hog enterprises[a]

	Two litter, Feb. & Aug. farrow	Two litter, May & Nov. farrow	One litter, June farrow
Production:			
Sow (cwt)	4.50	4.50	4.50
Butchers (cwt)	30.82	30.82	14.26
Variable cost:			
Protein supplement	$115.00	$115.00	$59.80
Vet. and drugs	$18.48	$18.48	$9.24
Breeding	$3.00	$3.00	$1.50
Power and equipment	$11.50	$11.50	$6.75
Custom trucking	$6.00	$6.00	$3.00
TOTAL VARIABLE COST	$153.98	$153.98	$80.29
Interest on investment	$12.72	$12.72	$9.89
Corn (bu)	200.00	200.00	104.00
Labor (hrs/unit of activity)			
Total	36.00	36.00	18.00
Dec.-Mar.	12.60	10.40	.70
Apr.-May	5.40	7.90	1.30
June-July	5.80	5.40	8.00
Aug.-Sept.	7.60	5.40	4.70
Oct.-Nov.	4.70	6.80	3.30

[a]These hog budgets were used on representative farms 5, 10,15,26, and 27.

Table 88. Representative farm budgets for large, specialized hog enterprises[a]

	Two litter, Feb. & Aug. farrow	Two litter, May & Nov. farrow	One litter, June farrow
Production:			
Sow (cwt)	4.50	4.50	4.50
Butchers (cwt)	33.12	33.12	15.41
Variable cost:			
Protein supplement	$115.00	$115.00	$59.80
Vet. and drugs	$18.48	$18.48	$9.24
Breeding	$3.00	$3.00	$1.50
Power and equipment	$11.50	$11.50	$6.75
Custom trucking	$6.00	$6.00	$3.00
TOTAL VARIABLE COST	$153.98	$153.98	$80.29
Interest on investment	$12.72	$12.72	$9.89
Corn (bu)	200.00	200.00	104.00
Labor (hrs/unit of activity)			
Total	32.00	32.00	16.00
Dec.-Mar.	11.20	9.30	.60
Apr.-May	4.80	7.00	1.20
June-July	5.10	4.80	7.10
Aug.-Sept.	6.70	4.80	4.10
Oct.-Nov.	4.20	6.10	3.00

[a]These hog budgets were used on representative farms 12,18 and 23.

(3) lubrication and repairs for other equipment

(4) fertilizer and lime

(5) insecticides and herbicides

(6) custom machine hire for pesticide application, fertilizer application, trucking, harvesting, and drying

(7) hail insurance, a net cost after settlement of loss claims and payment of dividends

(8) interest on preharvest costs for the duration of the crop season

(9) drying by owned equipment

(10) commercial storage

(11) baler twine

The variable costs that are included in the livestock budgets when applicable are:

(1) commercial feeds

(2) veterinary and drugs

(3) personal property taxes

(4) breeding fees

(5) power and equipment

(6) marketing

(7) interest on investment in animals for dairy, beef cows and hog activities. Interest on investment in beef feeders is charged internally in the model.

The prices used for the products that are not variable priced and for key inputs are shown in Table 89.

An example farm sub-model is shown in Table 90. Several of the activities also have coefficients in area or state rows but these are not shown. Tables 10 and 12 in Chapter IV illustrate the location in the matrix for most of these coefficients needed at the intersection of farm activities and area or state rows.

Table 89. Price assumptions for products that are not variable priced and for major inputs

Item	Unit	Price
		(Dollar)
Sell hay	Ton	20.00
Buy hay	"	24.00
Soybeans	Bushel	2.30
Price support payment	Acre	-[a]
Diverted acre payment	"	-[b]
Milk	Cwt.	4.92
Nitrogen (N)		
Corn	Pound	.05
Other crops	"	.10
Phosphorus (P)	"	.23
Potassium (K)	"	.05
Limestone, applied	Ton	4.10
Custom machine hire		
Pesticide application	Acre	1.00
Broadcast fertilizer	"	1.25
Sidedress fertilizer	"	2.00
Combine corn	"	8.50
Picker-sheller	"	7.50
Picker	"	6.50
Drying	Bushel	.10
Combine soybeans	Acre	6.50

[a]For an acre of corn base enrolled in the feed grain program this figure is:

(yield)(.5 base acre)($.30)

For an acre diverted to earn price support payment for five acres of corn base enrolled in the feed grain program this figure is:

(yield)(.5)(base acres)($.30) = (yield)($.75).

[b]For each acre diverted and earning diversion payment this figure is:

(yield)(.4)($1.31).

Table 89 (Continued)

Item	Unit	Price
Combine oats	Acre	6.00
Baling	Bale	.12
Trucking	Bushel	.04
Harvest silage	Ton	1.25
Protein supplement		
Dairy	Cwt.	5.50
Beef cow	"	5.50
Beef feeder	"	5.00
Hog	"	5.00
Interest	Dollar	.08
Seed		
Corn	Bushel	16.00
Soybean	"	3.25
Oat	"	.80
Alfalfa	Pound	.60
Red clover	"	.50
Brome	Pound	.35
Timothy	"	.25
Orchard grass	"	.33

Table 90. Matrix of coefficients for representative farm sub-model number 20 (large, cash grain farm in area 4)

Constraint[a]	Activity[b]								
	FC01	FC02	FC03	FC04	FC05	FC06	FC07	FC08	FC09
SR01	14.88[c]	23.60[c]	.93[c]	-.98[c]	-1.00[c]	80.06	59.94	20.00	-24.00
FR01									
FR02									
FR03									
FR04									
FR05									
FR06									
FR07									
FR08									
FR09									
FR10									
FR11									
FR12									
FR13			1.0	-1.00	-1.00				
FR14						1.0			
FR15							1.0		
FR16								1.0	-1.0
FR17									
FR18									
FR19									
FR20									
FR22	1.0								
FR23		1.0							
FR24									
FR25				-.98[c]	-1.00[c]				-24.00
FR26	14.88[c]	23.60[c]	.93[c]	-.98[c]	-1.00[c]	80.06	55.94	20.00	-24.00
FR27	14.88[c]	23.60[c]	-.465[c]	.98[c]	1.00[c]	-40.03	-27.97	-10.00	24.00

[a]The identification of the constraints is shown in Tables 2 and 4.

[b]The identification of the activities is shown in Table 5.

[c]Coefficients that vary with the price levels of pork, beef, and corn programmed. The coefficients shown are for a pork price of $14.88, beef price of $23.60, and a corn price of $.93.

Table 90 (Continued)

Constraints[a]	Activity[b]								
	FC10	FC11	FC12	FC13	FC14	FC15	FC16	FC17	FC18
SR01						-.08	-22.31	-34.292	-42.28
FR01	-1.0	-1.0	-1.0	-1.0	-1.0		2.70	3.744	4.44
FR02	-0.2586						.095	.152	.19
FR03	-0.1863	-1.0					.80	.992	1.12
FR04	-0.1965		-1.0				.555	.60	.63
FR05	-0.1815			-1.0			.14	.224	.28
FR06	-0.1771						1.11	1.776	2.22
FR07					-1.0		1.0	1.0	1.0
FR08									
FR09							1.0	1.0	1.0
FR10							1.0	1.0	.64
FR11							.203	.203	
FR12							-.50	-.20	
FR13							-53.375	-85.40	-106.75
FR14							-.20	-.20	
FR15							-.30		
FR16									
FR17									
FR18									
FR19									
FR20									
FR22									
FR23									
FR24						1.0			
FR25	-3.00	-3.00	-3.00	-3.00	-3.00	1.0	-21.63	-33.226	-40.96
FR26	-1.80	-1.80	-1.80	-1.80	-1.80		-21.63	-33.226	-40.96
FR27									

Table 90 (Continued)

Constraints[a]	Activity[b]								
	FC19	FC20	FC21	FC22	FC23	FC24	FC25	FC26	FC27
SR01	-23.77	-36.628	-45.20	54.22	-9.17	-6.95	-10.95		
FR01	4.51	6.64	8.06	3.01	1.84	.36	6.42		
FR02	.095	.152	.19	.06	.24				
FR03	.80	.992	1.12	.76	.14	.36			
FR04	.555	.60	.63	1.14	1.29		4.05		
FR05	2.86	4.576	5.72	.36	.16		2.37		
FR06	.20	.32	.40	.69	.02				
FR07	1.0	1.0	1.0	1.0	1.0	1.0			
FR08								-2.32	
FR09	1.0	1.0	1.0	1.0					
FR10	1.0	1.0	.64						
FR11	.203	.203				-1.0			
FR12	-.50	-.20			-1.0	.50			
FR13					-34.945				
FR14	-.20	-.20							
FR15	-.30								
FR16						-1.0	1.0	1.0	
FR17							-3.03		1.0
FR18	-2.765	-4.424	-5.53						-1.0
FR19									
FR20									
FR22									
FR23									
FR24									
FR25	-23.20	-35.75	-44.11	-18.62	-8.96	-6.44	-10.95		
FR26	-23.20	-35.75	-44.11	54.80	-8.96	-6.44	-10.95		
FR27				-36.71					

Table 90 (Continued)

Constraints[a]	Activity[b]								
	FC28	FC29	FC30	FC31	FC33	FC34	FC35	FC36	FC37
SR01	-166.70	-166.70	-90.18	-24.50	-26.72	-25.72	-23.25	-21.21	-18.15
FR01	50.00	50.00	25.00		14.40	11.52	9.60	9.60	7.68
FR02	17.50	14.50	.90		5.18	4.15	5.18		
FR03	7.50	11.00	1.80		2.53	2.03	1.94	3.21	2.56
Fr04	8.00	7.50	11.10		1.87	1.50	1.92	3.03	2.43
FR05	10.50	7.50	6.50		2.51	2.00		3.36	2.69
FR06	6.50	9.50	4.60		2.30	1.84	.56		
FR07									
FR08						.34			.82
FR09									
FR10									
FR11									
FR12									
FR13	200.00	200.00	104.00		60.00	58.00	45.00	45.00	45.00
FR14									
FR15									
FR16									
FR17									
FR18					.85	.75	.83	.83	.47
FR19	1.0			-1.0					
FR20		1.0	1.0	-1.0					
FR22	-35.32	-35.32	-18.76						
FR23					-10.46	-10.46	-10.73	-10.73	-10.73
FR24				-8.17	-112.34	-112.34	-143.72	-143.72	-143.72
FR25	-153.98	-153.98	-80.29	-24.50	-147.90	-146.92	-182.54	-180.54	-177.54
FR26	-153.98	-153.98	-80.29		-147.90	-146.92	-182.54	-180.54	-177.54
FR27									

XIII. APPENDIX D: ADDITIONAL MODEL RESULTS

Other results from the fifteen solutions to the model are presented in this appendix. The first six tables show the production of pork and beef again but in a different form. The production of pork is shown as the number of litters of hogs on each representative farm if it is optimally organized. The production of beef for each representative farm is shown as the number of head of cattle fed.

Table 97 gives the total number of livestock on Iowa farms at each price combination. The number of beef cows ranges from zero up to 580,600. The larger numbers of beef cows are in the model solutions that have a low pork-corn price ratio and a high beef-pork price ratio. The change to a high pork-corn price relationship forces the beef cows out of the optimal solution because the beef cows cannot compete for the labor supply. The number of dairy cows is quite constant across all price relationships because dairy cows are found only on the specialized dairy farms. The marginal value of relaxing the type-of-farm constraint showed that the numbers of dairy cows would decrease if they were not needed to satisfy the type-of-farm constraint on the dairy farms.

The next seven tables are concerned with crop production. Table 98 shows the total production for corn, soybeans and oats if all farms are optimally organized. The bushels of corn are about fifty percent higher than recent historical production in Iowa because of the internally generated demand for feed grains by the livestock activities. Soybeans are somewhat lower than recent historical production because corn has a higher priority on the use of row-cropland and labor. Oats take less labor and also are used as a feed grain so the estimates for oats are two to three times higher than recent levels of production.

Tables 99-103 show the corresponding acres of corn, soybeans and oats as well as rotation meadow and feed grain diversion. The acres of rotation meadow range from 1,672,700 acres up to 2,046,400 acres while the acres diverted from feed grain production under the Government program range from 1,943,000 acres to 2,751,900 acres.

The last table of crop information, Table 104 shows the quantity of corn sold out of the state at each price combination. The maximum quantity that was allowed to be sold was 440,000,000 bushels and this limited the quantity sold in about one-half of the solutions.

The next six tables give the shadow price values for the row-cropland restraint and the corn base restraint. The marginal value of an additional acre of corn base increased significantly on most farms as the price of corn was increased from \$.93 to \$1.17.

The minimum returns equation in each representative farm sub-model is constructed very similar to the objective function. However, the minimum returns equation is only for the representative farm while the objective function for the interfirm competition model is a common equation for all farms. Thus, the minimum returns equation gives an "objective function" value for each farm. These values for each individual farm are shown in Tables 111-113.

Table 91. Number of litters of hogs on each representative farm when the price of corn is $.93

Pork price	14.88	17.11			19.34
Beef price	23.60	19.03	21.32	23.60	23.60
Representative farm number					
1	20.2	17.9	18.1	18.0	16.4
2	100.5	107.0	106.9	102.4	111.2
3	43.5	40.7	39.9	39.9	36.2
4	72.8	31.0	62.3	68.9	64.9
5	148.7	163.4	163.4	152.4	163.4
6	33.7	30.0	32.1	33.5	40.6
7	90.2	104.5	104.5	97.6	103.3
8	32.4	34.6	32.1	34.6	29.1
9	12.0	63.1	75.8	12.0	96.5
10	117.5	128.3	128.3	128.3	129.2
11	11.3	9.9	9.8	9.6	9.8
12	76.0	77.8	77.8	77.8	77.8
13	79.9	85.8	86.0	86.2	86.3
14	22.5	28.8	28.8	28.8	25.5
15	142.9	163.1	163.5	142.6	166.2
16	16.7	14.9	14.9	14.9	13.3
17	14.0	6.0	6.0	12.2	14.9
18	122.9	125.4	125.5	125.4	125.4
19	96.7	103.7	105.0	96.2	106.3
20	13.1	42.3	39.2	42.1	35.7
21	103.2	139.7	142.2	131.9	145.5
22	15.3	13.6	13.6	13.6	12.3
23	111.2	113.1	113.1	113.1	113.1
24	110.3	112.4	112.4	112.4	112.4
25	10.5	11.0	-	-	-
26	75.2	56.0	76.6	98.7	90.9
27	166.2	187.7	184.2	178.9	187.5

Table 92. Number of litters of hogs on each representative farm when the price of corn is $1.05

Pork price	15.54		18.06		20.58
Beef price	22.79	20.21	22.79	25.35	22.79
Representative farm number					
1	21.3	18.7	19.0	18.7	16.8
2	101.1	110.0	109.2	106.9	111.2
3	43.5	42.1	40.6	40.6	37.3
4	70.8	35.5	64.9	71.9	74.7
5	151.7	163.4	163.4	155.4	168.8
6	33.2	30.1	32.2	41.5	35.7
7	91.0	104.0	100.9	96.9	104.0
8	23.6	35.4	35.4	35.4	32.2
9	12.0	79.5	56.7	12.0	92.5
10	117.5	128.3	128.4	128.3	129.2
11	11.8	11.5	11.5	11.5	10.3
12	74.5	76.3	76.3	76.3	76.3
13	82.3	84.7	84.7	84.7	84.7
14	25.8	29.9	29.9	29.9	26.7
15	145.1	166.7	158.2	148.1	168.2
16	17.8	15.6	15.6	15.6	14.0
17	12.7	3.0	3.6	9.2	12.5
18	124.6	125.0	125.0	125.0	125.0
19	97.0	107.3	104.0	100.2	107.1
20	11.2	42.9	8.0	11.2	35.6
21	105.9	143.5	140.0	111.6	152.3
22	14.3	12.7	12.7	12.7	11.5
23	109.8	109.8	109.8	109.8	109.8
24	110.4	110.4	110.4	110.4	110.1
25	5.2	-	-	-	-
26	80.0	55.6	77.1	97.5	84.6
27	178.9	187.7	185.7	186.1	185.7

Table 93. Number of litters of hogs on each representative farm when the price of corn is $1.17

Pork price	15.91		18.72		21.53
Beef price	26.83	21.07	23.95	26.83	26.83
Representative farm number					
1	22.6	19.7	19.7	19.7	17.5
2	101.3	111.2	107.1	106.9	106.9
3	31.8	44.1	40.9	40.9	38.0
4	71.5	35.2	69.3	72.8	79.8
5	151.5	163.4	157.8	155.6	152.8
6	33.8	30.2	39.2	43.7	31.2
7	93.2	103.5	96.5	96.1	103.3
8	8.0	36.7	36.7	36.7	33.2
9	12.0	76.5	41.8	19.5	12.0
10	117.5	129.2	128.3	128.3	129.2
11	12.6	12.3	12.3	12.3	10.9
12	73.2	75.0	75.0	75.0	75.0
13	81.2	83.3	83.3	83.3	83.3
14	26.2	31.8	31.8	31.8	28.2
15	149.8	157.6	144.5	146.3	147.6
16	19.0	16.6	16.6	16.6	14.7
17	10.9	3.0	9.3	13.5	13.4
18	124.5	124.0	124.5	124.5	124.5
19	96.5	107.1	101.6	100.1	100.1
20	8.0	44.2	8.0	13.8	20.1
21	102.7	144.0	115.6	106.8	138.0
22	13.6	12.0	12.0	12.0	10.7
23	105.1	106.9	106.9	106.9	106.9
24	105.9	108.5	108.5	108.5	108.5
25	11.0	-	-	-	-
26	81.8	57.7	90.5	96.4	88.5
27	178.7	187.7	187.5	187.5	181.8

Table 9.4. Number of beef feeders on each representative farm when the price of corn is $.93

Pork price	14.88		17.11		19.34
Beef price	23.60	19.03	21.32	23.60	23.60
Representative farm number					
1	-	-	-	-	-
2	11.5	-	-	11.5	-
3	1.1	-	-	-	-
4	255.1	246.1	281.7	267.5	275.2
5	29.5	-	-	29.8	-
6	88.1	105.2	105.6	145.9	136.4
7	14.8	-	-	11.5	-
8	3.4	-	-	-	-
9	425.2	304.0	300.3	486.7	333.2
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	8.5	-	-	-	-
14	-	-	-	-	-
15	38.0	-	-	51.6	-
16	-	-	-	-	-
17	-	-	-	-	-
18	1.1	-	-	-	-
19	20.8	-	-	20.8	2.5
20	39.3	-	-	-	-
21	66.7	-	-	33.0	12.1
22	-	-	-	-	-
23	-	-	-	-	-
24	-	-	-	-	-
25	-	-	-	-	-
26	186.2	197.7	241.3	280.8	292.3
27	49.2	-	-	22.7	-

Table 95. Number of beef feeders on each representative farm when the price of corn is $1.05

Pork price	15.54		18.06		20.58
Beef price	22.79	20.21	22.79	25.35	22.79
Representative farm number					
1	-	-	-	-	-
2	11.5	-	5.9	11.5	-
3	1.3	-	-	-	-
4	264.8	241.8	276.7	262.8	286.6
5	21.1	-	-	21.0	-
6	93.4	105.2	104.4	119.1	129.5
7	16.9	-	-	10.9	-
8	21.2	-	-	-	-
9	437.9	328.6	394.0	491.5	349.6
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	37.6	-	-	33.0	-
16	-	-	-	-	-
17	-	-	-	-	-
18	0.9	-	-	-	-
19	20.5	-	8.7	17.2	-
20	46.3	-	49.2	41.0	-
21	58.8	-	6.2	54.7	-
22	-	-	-	-	-
23	-	-	-	-	-
24	-	-	-	-	-
25	-	-	-	-	-
26	214.2	195.0	240.0	272.7	300.1
27	22.8	-	-	-	-

Table 96. Number of beef feeders on each representative farm when the price of corn is $1.17

Pork price	15.91		18.72		21.53
Beef price	26.83	21.07	23.95	26.83	26.83
Representative farm number					
1	-	-	-	-	-
2	11.5	-	11.5	11.5	11.5
3	17.8	-	-	-	-
4	251.8	238.8	271.0	257.3	269.2
5	21.0	-	21.0	21.0	35.2
6	88.0	104.8	123.1	122.9	150.8
7	16.7	-	13.5	11.9	0.4
8	38.4	-	-	-	-
9	458.3	310.7	430.5	471.0	491.7
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	22.6	-	46.8	37.2	48.8
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	20.8	-	14.0	17.1	17.1
20	47.1	-	51.1	39.3	27.7
21	61.8	-	50.7	61.8	25.9
22	-	-	-	-	-
23	-	-	-	-	-
24	-	-	-	-	-
25	-	-	-	-	-
26	190.5	201.3	277.6	263.9	278.8
27	22.8	-	-	-	15.5

Table 97. State total numbers of livestock produced

Corn price	Pork price	Beef price	Beef cows	Dairy cows	Beef feeders	Litters of hogs
($/bu)	($/cwt)	($/cwt)	(1000 hd)	(1000 hd)	(100 hd)	(1000 lit)
$.93	$14.88	$23.60	552.1	285.8	4,590.0	9,206.1
	17.11	19.03	341.1	290.6	2,472.4	10,096.4
		21.32	244.2	283.4	2,674.7	10,303.5
		23.60	138.9	282.5	4,590.0	9,698.3
	19.34	23.60	83.6	277.8	2,962.1	10,458.5
1.05	15.54	22.79	539.1	286.2	4,590.0	9,281.8
	18.06	20.21	68.3	289.1	2,522.6	10,264.0
		22.79	330.7	282.0	3,344.1	10,023.1
		25.35	192.3	286.2	4,590.0	9,560.7
	20.58	22.79	-	267.0	2,944.1	10,575.6
1.17	15.91	26.83	580.6	291.6	4,590.0	9,173.7
	18.72	21.07	326.6	285.4	2,459.6	10,192.5
		23.95	99.0	279.4	4,590.0	9,633.6
		26.83	156.5	288.0	4,590.0	9,564.5
	21.53	26.83	-	287.0	4,590.0	9,767.2

Table 98. Total production of corn, soybeans and oats for the state

Corn price	Pork price	Beef price	Corn	Soybeans	Oats
($/bu)	($/cwt)	($/cwt)	(1000 bu)	(1000 bu)	(1000 bu)
$.93	$14.88	$23.60	1,515,256	119,021	216,358
	17.11	19.03	1,425,445	135,410	241,882
		21.32	1,423,759	133,331	232,050
		23.60	1,475,420	115,100	221,335
	19.34	23.60	1,413,735	110,272	376,543
1.05	15.54	22.79	1,520,264	115,966	221,733
	18.06	20.21	1,460,327	121,835	266,428
		22.79	1,488,308	106,194	252,216
		25.35	1,530,905	96,867	254,389
	20.58	22.79	1,433,561	91,427	318,179
1.17	15.91	26.83	1,555,749	112,763	224,192
	18.72	21.07	1,475,529	104,276	268,811
		23.95	1,528,164	90,111	272,963
		26.83	1,529,223	93,241	258,733
	21.53	26.83	1,513,877	66,353	329,201

Table 99. Acres of corn

Corn price	Pork price	Beef price	Area of state 1	2	3	4	5	State total
($/bu)	($/cwt)	($/cwt)	(1000 Ac)	(1000 Ac)	(1000 Ac)	(1000 Ac)	(1000 Ac)	(1000 Ac)
$ .93	$ 14.88	$23.60	4590.7	2188.2	3011.2	4254.2	723.2	14,767.5
	17.11	19.03	4500.7	2062.1	2825.7	3782.0	714.2	13,884.7
		21.32	4628.8	2023.4	2826.3	3654.7	713.5	13,846.7
		23.60	4692.7	2148.4	3055.5	3832.5	716.2	14,445.3
	19.34	23.60	4635.1	2111.6	2833.3	3551.0	661.3	13,792.3
1.05	15.54	22.79	4612.1	2240.9	2977.5	4313.9	693.9	14,838.3
	18.06	20.21	4660.4	2166.2	2834.2	3836.9	727.1	14,224.8
		22.79	4699.7	2164.8	2946.1	3981.4	670.7	14,462.7
		25.35	4753.0	2249.9	3042.2	4225.5	698.3	14,968.9
	20.58	22.79	4758.6	2224.9	2832.9	3574.6	631.0	14,022.0
1.17	15.91	26.83	4822.6	2372.4	2964.5	4370.4	682.6	15,212.5
	18.72	21.07	4774.7	2147.4	2978.1	3823.4	661.5	14,385.1
		23.95	4776.6	2259.5	3099.2	4203.6	638.3	14,977.2
		26.83	4761.3	2249.5	3078.7	4182.2	667.8	14,939.5
	21.53	26.83	4865.4	2296.5	3078.7	3957.3	662.4	14,860.3

Table 100. Acres of soybeans

Corn price	Pork price	Beef price	Area of state 1	2	3	4	5	State total
($/bu)	($/cwt)	($/cwt)	(1000 AC)	(100 Ac)	(1000 Ac)	(1000 Ac)	(1000 Ac)	(1000 Ac)
$ .93	$14.88	$23.60	2312.8	194.4	83.6	1037.6	-	3628.4
	17.11	19.03	2309.7	310.3	260.7	1251.9	3.0	4135.6
		21.32	2166.8	316.6	269.8	1319.2	3.4	4075.8
		23.60	2128.9	149.3	10.9	1226.3	-	3515.4
	19.34	23.60	1882.6	173.7	363.6	950.6	-	3370.4
1.05	15.54	22.79	2296.3	168.8	83.3	971.5	15.0	3535.0
	18.06	20.21	2030.4	236.8	373.3	1083.7	-	3723.9
		22.79	1942.1	202.2	85.7	1010.8	-	3240.6
		25.35	1906.1	143.7	20.5	882.8	-	2953.1
	20.58	22.79	1387.2	133.4	419.9	860.5	-	2801.2
1.17	15.91	26.83	2297.4	115.9	74.0	928.9	21.4	3437.6
	18.72	21.07	1886.2	167.9	56.4	1074.1	-	3184.6
		23.95	1708.9	146.0	-	894.1	-	2749.0
		26.83	1815.5	146.0	-	856.0	26.4	2843.9
	21.53	26.83	1453.6	136.0	-	425.7	-	2015.3

Table 101. Acres of oats

Corn price	Pork price	Beef price	Area of state 1	2	3	4	5	State total
($/bu)	($/cwt)	($/cwt)	(1000 Ac)	(1000 Ac)	(1000 Ac)	(1000 Ac)	(1000 Ac)	(1000 Ac)
$ .93	$14.88	$23.60	411.3	697.5	1640.4	407.2	313.1	3469.5
	17.11	19.03	524.7	838.5	1824.1	377.7	314.7	3879.8
		21.32	442.1	789.2	1835.7	353.5	320.6	3741.1
		23.60	418.0	640.7	1811.8	387.1	306.5	3564.1
	19.34	23.60	678.1	666.9	1931.7	695.2	386.4	4358.3
1.05	15.54	22.79	422.3	714.9	1644.1	453.2	314.2	3548.6
	18.06	20.21	672.1	764.4	1940.8	522.0	330.5	4229.8
		22.79	608.2	681.7	1783.4	546.0	371.0	3990.4
		25.35	611.0	702.5	1811.1	592.4	312.2	4029.1
	20.58	22.79	1178.0	695.7	1981.8	790.9	278.5	4924.9
1.17	15.91	26.83	422.0	739.7	1650.6	472.7	303.2	3588.2
	18.72	21.07	746.6	811.8	1785.9	521.9	369.0	4235.2
		23.95	736.3	719.1	1843.9	588.4	405.5	4293.2
		26.83	659.0	706.6	1825.5	589.8	309.7	4090.6
	21.53	26.83	1061.0	745.8	1825.5	1082.4	355.7	5070.4

Table 102. Acres of rotation meadow

Corn price	Pork price	Beef price	Area of state 1	2	3	4	5	State total
($/bu)	($/cwt)	($/cwt)	(1000 Ac)	(1000 Ac)	(1000 Ac)	(1000 Ac)	(1000 Ac)	(1000 Ac)
$ .93	$14.88	$23.60	337.2	599.0	341.4	380.6	388.2	2046.4
	17.11	19.03	223.8	457.9	157.7	446.2	386.6	1672.0
		21.32	306.2	507.1	146.3	470.3	380.7	1810.6
		23.60	330.4	655.8	170.0	435.4	396.6	1988.2
	19.34	23.60	303.1	629.6	50.1	557.4	343.0	1883.2
1.05	15.54	22.79	326.2	581.5	337.7	369.2	387.1	2001.8
	18.06	20.21	193.7	532.1	41.0	440.8	370.7	1578.4
		22.79	314.4	614.9	198.4	413.0	357.0	1897.7
		25.35	311.4	593.9	170.7	365.6	399.5	1841.1
	20.58	22.79	302.0	600.8	-	533.8	350.2	1786.8
1.17	15.91	26.83	326.2	556.8	331.0	362.5	398.2	1974.7
	18.72	21.07	178.0	484.6	196.0	457.7	364.9	1681.2
		23.95	325.0	577.4	137.9	369.8	339.5	1749.6
		26.83	302.7	589.9	156.3	417.8	391.6	1858.3
	21.53	26.83	315.0	550.8	156.3	480.1	375.0	1877.2

Table 103. Acres of feed grain diversion

Corn price	Pork price	Beef price	Area of state 1	2	3	4	5	State total
($/bu)	($/cwt)	($/cwt)	(1000 Ac)	(1000 Ac)	(1000 Ac)	(1000 Ac)	(1000 Ac)	(1000 Ac)
$ .93	$14.88	$23.60	882.2	503.3	157.9	613.8	87.2	2244.4
	17.11	19.03	975.3	513.5	166.4	836.0	93.2	2584.4
		21.32	990.1	545.8	156.8	895.9	93.5	2682.1
		23.60	964.1	588.1	186.4	812.2	92.4	2643.2
	19.34	23.60	1035.2	600.6	55.8	939.2	121.1	2751.9
1.05	15.54	22.79	877.2	476.1	192.0	585.7	101.6	2232.6
	18.06	20.21	977.5	482.8	45.7	810.2	83.3	2399.5
		22.79	969.7	519.0	221.0	742.2	113.0	2564.9
		25.35	952.6	492.2	190.1	627.3	101.6	2363.8
	20.58	22.79	908.4	527.5	-	933.6	132.4	2501.9
1.17	15.91	26.83	665.6	397.5	214.2	559.2	106.5	1943.0
	18.72	21.07	948.7	570.5	218.2	816.6	116.4	2670.4
		23.95	987.3	480.3	153.6	637.6	128.5	2387.3
		26.83	995.6	490.3	174.1	647.7	116.2	2423.9
	21.53	26.83	839.1	453.3	174.1	747.9	118.7	2333.1

Table 104. Bushels of corn sold out of the state

Corn price	Pork price	Beef price	Quantity
($/bu)	($/cwt)	($/cwt)	(1,000 bu)
.93	14.88	23.60	440,000
	17.11	19.03	384,981
		21.32	348,681
		23.60	354,575
	19.34	23.60	329,993
1.05	15.54	22.79	440,000
	18.06	20.21	413,965
		22.79	415,380
		25.35	440,000
	20.58	22.79	360,423
1.17	15.91	26.83	440,000
	18.72	21.07	440,000
		23.95	440,000
		26.83	440,000
	21.53	26.83	440,000

Table 105. Marginal value of one additional acre of row-cropland when the price of corn is $.93

Pork price	14.88		17.11		19.34
Beef price	23.60	19.03	21.32	23.60	23.60
Farm number					
1	29.27	30.47	30.47	30.47	31.98
2	10.24	4.14	1.92	2.20	-
3	21.71	21.78	23.07	23.01	24.04
4	10.47	6.75	5.83	1.98	-
5	14.19	11.13	7.25	8.25	1.26
6	23.74	50.27	22.29	19.28	17.83
7	34.18	37.65	28.02	34.96	22.57
8	33.44	34.67	34.30	34.82	36.10
9	23.56	22.09	23.69	19.91	18.79
10	30.86	22.55	23.72	24.90	16.21
11	63.59	105.95	101.72	91.95	58.18
12	70.72	81.21	81.21	81.21	90.96
13	47.95	46.91	45.19	52.88	23.85
14	43.18	41.60	41.51	46.81	41.91
15	28.91	23.93	24.89	25.24	13.77
16	27.99	29.23	29.23	29.23	30.74
17	-	-	-	-	-
18	2.80	-	-	-	-
19	12.59	2.45	1.97	1.12	-
20	20.14	19.22	18.99	19.04	20.27
21	16.63	5.81	5.51	12.80	-
22	18.13	17.44	17.44	16.08	15.41
23	56.43	64.97	64.97	66.05	73.90
24	44.65	49.22	49.22	50.37	56.59
25	17.13	0.23	1.87	-	-
26	46.82	46.45	50.69	50.70	51.94
27	42.81	27.84	51.95	49.57	37.64

Table 106. Marginal value of one additional acre of row-cropland when the price of corn is $1.05

Pork price	15.54		18.06		20.58
Beef price	22.79	20.21	22.79	25.35	22.79
Farm number					
1	28.17	25.23	25.23	25.99	26.65
2	7.28	-	-	-	-
3	19.92	13.95	14.04	15.36	15.07
4	10.74	2.33	1.89	0.26	-
5	11.19	4.38	3.08	2.28	-
6	21.63	57.33	24.65	17.81	29.11
7	29.70	35.83	23.82	27.82	23.90
8	32.40	25.98	26.29	27.39	28.12
9	21.69	19.40	20.38	22.58	15.56
10	28.94	19.26	19.97	21.28	13.85
11	54.60	65.25	65.25	64.17	68.15
12	77.58	94.82	94.82	94.04	107.25
13	48.89	47.23	40.66	50.13	27.20
14	44.18	38.69	33.90	40.36	26.85
15	27.56	18.98	18.85	20.30	9.49
16	27.00	24.39	24.39	25.10	25.83
17	-	-	-	-	-
18	-	-	-	-	-
19	9.65	-	-	-	-
20	18.13	9.79	9.39	11.05	10.12
21	14.45	2.29	3.98	6.11	-
22	17.34	11.78	11.78	11.53	10.96
23	62.42	77.46	77.46	77.65	88.98
24	48.91	59.10	61.77	59.30	72.27
25	6.98	8.81	-	-	-
26	47.86	57.88	54.68	53.04	59.00
27	44.41	38.76	47.04	43.70	59.82

Table 107. Marginal value of one additional acre of row-cropland when the price of corn is $1.17

Pork price	15.91		18.72		21.53
Beef price	26.83	21.07	23.95	26.83	26.83
Farm number					
1	25.37	22.07	24.05	24.45	23.83
2	5.50	-	-	-	-
3	16.66	7.95	12.34	13.02	10.71
4	9.48	0.74	-	-	-
5	8.56	1.44	-	-	-
6	30.00	57.83	21.02	21.86	32.61
7	31.10	27.87	24.54	28.90	37.71
8	34.14	21.88	25.17	25.77	24.15
9	17.71	19.18	23.37	26.24	38.08
10	27.03	17.22	17.81	19.74	11.33
11	59.89	71.18	68.34	67.77	73.94
12	84.46	104.54	102.59	102.20	119.34
13	46.86	38.76	46.29	53.94	80.29
14	41.87	32.98	37.06	42.23	57.72
15	24.82	15.07	17.34	21.10	20.82
16	24.41	21.48	23.33	23.70	23.23
17	-	-	-	-	-
18	-	-	-	-	-
19	7.75	-	-	-	-
20	13.65	4.32	7.99	8.85	6.58
21	11.14	0.36	3.30	3.87	-
22	14.57	9.72	11.27	11.78	10.42
23	68.73	86.36	85.32	84.95	99.76
24	53.23	80.28	79.23	78.85	93.01
25	4.17	-	-	0.13	-
26	51.68	65.52	57.13	55.85	69.97
27	43.48	46.93	36.55	35.81	28.28

Table 108. Marginal value of one additional acre of corn base when the price of corn is $.93

Pork price	14.88		17.11		19.34
Beef price	23.60	19.03	21.32	23.60	23.60
Farm number					
1	17.52	21.01	21.01	21.01	22.05
2	14.22	14.14	14.99	17.31	13.34
3	5.63	6.08	6.54	6.13	5.60
4	13.21	12.31	14.61	15.37	18.05
5	8.79	10.79	12.88	12.48	15.62
6	11.65	-	8.59	13.05	12.88
7	-	-	-	-	-
8	2.69	0.85	2.14	4.65	3.08
9	12.11	10.14	11.34	13.05	12.97
10	3.37	3.15	4.29	6.49	7.19
11	5.86	11.27	10.47	8.64	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	6.14	-	-	1.65	-
16	31.01	35.37	35.37	35.37	36.86
17	19.17	14.88	14.88	15.01	8.02
18	26.98	28.16	15.11	17.89	2.71
19	15.78	9.53	9.35	18.99	7.90
20	10.68	6.77	7.00	8.80	9.13
21	8.39	7.56	7.58	6.94	10.15
22	10.47	9.43	9.43	9.41	8.87
23	-	-	-	-	-
24	-	-	-	-	-
25	9.00	15.67	14.45	13.81	13.58
26	-	-	-	-	-
27	-	-	-	-	-

Table 109. Marginal value on one additional acre of corn base when the price of corn is $1.05

Pork price	15.54		18.06		20.58
Beef price	22.79	20.21	22.79	25.35	22.79
Farm number					
1	23.31	40.60	40.60	38.14	42.38
2	15.04	15.54	15.78	16.75	13.23
3	6.57	10.95	12.04	11.40	12.32
4	14.01	14.57	16.11	16.94	17.83
5	10.13	13.91	14.95	14.68	17.03
6	12.02	-	8.07	12.49	5.77
7	-	-	1.96	-	-
8	2.86	3.18	5.29	5.37	7.31
9	12.31	11.22	12.77	10.84	12.24
10	3.47	4.77	6.95	6.82	10.77
11	0.71	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	8.35	-	-	3.06	-
16	37.77	58.01	58.01	55.18	60.37
17	19.61	15.06	17.01	17.40	11.02
18	27.81	35.86	17.58	23.01	8.68
19	17.07	9.59	12.12	18.28	7.21
20	12.11	10.26	12.05	11.62	12.88
21	9.67	8.80	9.71	8.65	12.34
22	10.13	8.78	8.78	8.77	7.94
23	-	-	-	-	-
24	-	-	-	-	-
25	12.92	5.80	12.26	12.24	5.96
26	-	-	-	-	-
27	-	-	-	-	-

Table 110. Marginal value of one additional acre of corn base when the price of corn is $1.17

Pork price	15.91		18.72		21.53
Beef price	26.83	21.07	23.95	26.83	26.83
Farm number					
1	33.46	52.67	46.23	44.95	53.81
2	15.33	14.92	16.28	16.32	14.63
3	9.34	12.88	12.60	12.17	13.33
4	14.82	16.27	18.19	18.32	18.45
5	11.12	15.76	15.57	15.40	17.89
6	7.79	-	10.73	10.29	4.26
7	-	-	-	-	-
8	-	5.70	5.94	6.99	10.17
9	13.05	12.40	9.96	8.88	2.07
10	4.67	7.04	7.85	8.47	13.30
11	-	-	-	-	-
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	9.53	0.05	-	0.17	1.22
16	49.48	71.96	64.57	63.10	73.61
17	21.24	14.67	17.24	17.02	7.74
18	35.80	34.76	26.02	27.95	34.90
19	17.88	8.76	16.53	17.55	16.94
20	12.88	12.57	12.68	12.83	16.31
21	10.44	9.63	9.37	9.55	13.25
22	9.74	8.49	8.53	8.55	7.65
23	-	-	-	-	-
24	-	-	-	-	-
25	13.88	11.35	13.65	13.87	11.94
26	-	-	-	-	-
27	-	-	-	-	-

Table 111. Average returns above variable costs on each representative farm when the price of corn is $.93

Pork price	14.88		17.11		19.34
Beef price	23.60	19.03	21.32	23.60	23.60
	(Dollar)	(Dollar)	(Dollar)	(Dollar)	(Dollar)
Representative farm number					
1	9,238	9,732	9,851	9,778	10,310
2	17,049	21,534	21,533	21,203	25,834
3	23,735	25,070	24,994	24,994	25,971
4	31,178	25,512	30,396	33,770	35,389
5	32,658	39,460	39,460	38,602	45,968
6	11,508	10,381	11,864	13,696	15,052
7	13,291	17,921	17,920	17,491	21,942
8	18,782	19,771	19,276	19,776	20,131
9	31,138	27,170	30,570	31,861	38,518
10	25,199	29,644	29,644	29,645	34,766
11	5,991	5,991	5,991	5,991	6,102
12	11,949	14,857	14,857	14,857	18,147
13	11,386	14,665	14,680	14,681	18,090
14	15,985	15,772	15,772	15,772	16,455
15	26,351	32,720	32,998	31,352	39,340
16	7,654	8,064	8,064	8,064	8,390
17	13,239	12,353	12,353	13,622	14,470
18	19,857	25,148	25,150	25,142	30,417
19	15,700	19,953	20,053	19,431	24,153
20	21,883	24,932	24,238	24,900	25,328
21	27,632	34,851	35,056	33,792	39,731
22	12,349	12,885	12,885	12,885	13,331
23	15,919	20,370	20,370	20,370	25,112
24	14,535	19,212	19,213	19,213	23,697
25	23,733	24,328	22,688	22,660	21,374
26	24,281	21,581	25,354	30,931	33,422
27	25,556	33,717	33,545	33,111	41,197

Table 112. Average returns above variable costs on each representative farm when the price of corn is $1.05

Pork price	15.54		18.06		20.58
Beef price	22.79	20.21	22.70	25.35	22.79
Representative farm number	(Dollar)	(Dollar)	(Dollar)	(Dollar)	(Dollar)
1	10,766	11,364	11,485	11,364	11,890
2	18,389	23,320	23,160	23,110	28,303
3	25,346	27,424	27,153	27,155	28,561
4	33,776	29,259	36,110	40,144	38,896
5	34,831	42,233	42,233	41,926	49,403
6	12,393	12,214	13,888	15,997	15,758
7	14,408	19,504	19,299	19,089	24,145
8	20,566	22,304	22,367	22,368	23,551
9	34,075	34,145	36,693	40,878	42,786
10	26,532	31,800	31,805	31,800	37,596
11	6,723	6,984	6,984	6,984	7,273
12	12,412	15,781	15,781	15,781	19,432
13	12,201	15,668	15,668	15,668	19,441
14	18,457	18,785	18,785	18,785	19,552
15	28,462	35,304	36,031	35,453	42,757
16	9,012	9,511	9,511	9,511	9,904
17	13,517	12,487	12,604	13,594	14,499
18	21,250	27,232	27,228	27,227	33,187
19	17,038	21,789	21,644	21,524	26,603
20	24,566	27,455	24,766	25,397	27,607
21	30,189	37,200	37,334	35,826	43,388
22	12,663	13,217	13,217	13,217	13,665
23	16,064	21,268	21,269	21,269	26,473
24	15,413	20,389	20,389	20,389	25,312
25	24,279	23,837	22,632	23,702	18,533
26	26,625	24,719	29,962	35,959	35,493
27	28,340	36,915	36,771	36,840	45,086

Table 113. Average returns above variable costs on each representative farm when the price of corn is $1.17

Pork price	15.91		18.72		21.53
Beef price	26.83	21.07	23.95	26.83	26.83
	(Dollar)	(Dollar)	(Dollar)	(Dollar	(Dollar)
Representative farm number					
1	12,197	12,926	12,926	12,926	13,489
2	19,126	24,599	24,180	24,303	29,668
3	27,076	30,071	28,919	28,919	30,990
4	37,663	31,526	37,196	41,299	44,830
5	35,921	44,159	43,277	43,641	50,766
6	13,726	13,517	14,158	16,682	17,274
7	15,080	20,561	19,823	19,946	25,702
8	22,963	24,820	24,820	24,820	26,358
9	40,174	37,330	36,146	41,302	40,727
10	28,109	33,347	33,296	33,296	39,763
11	7,779	8,060	8,060	8,060	8,411
12	12,761	16,302	16,302	16,302	20,308
13	12,620	16,235	16,235	16,235	20,399
14	21,507	21,628	21,628	21,628	22,569
15	30,692	37,657	36,128	37,282	43,630
16	10,287	10,899	10,899	10,899	11,372
17	13,731	13,001	14,075	14,290	14,789
18	22,004	28,551	28,628	28,628	35,245
19	17,783	23,075	22,571	22,635	27,603
20	27,109	29,968	26,966	28,042	29,306
21	31,938	38,785	37,016	37,189	44,450
22	12,893	13,471	13,462	13,462	13,926
23	16,312	21,606	21,606	21,606	27,258
24	15,522	20,968	20,968	20,968	26,411
25	25,565	23,474	22,347	24,348	23,494
26	29,095	27,378	31,269	35,962	39,939
27	29,654	39,147	39,129	39,129	47,853